American Denture Society Meeting, Chicago, Ill., Feb. 3 and 4, 1961.
American Academy of Crown and Bridge Prosthodontics Meeting, Chicago, Ill., Feb. 4 and 5, 1961.
American Academy of Restorative Dentistry Meeting, Chicago, Ill., Feb. 4 and 5, 1961.

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THE UNIVERSITY OF MICHIGAN
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THE JOURNAL OF PROSTHETIC DENTISTRY

VOLUME 11 JANUARY-FEBRUARY, 1961 NUMBER 1

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FIXED PARTIAL DENTURES
OPERATIVE DENTISTRY

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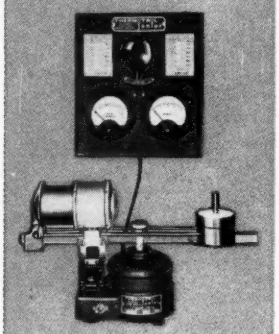

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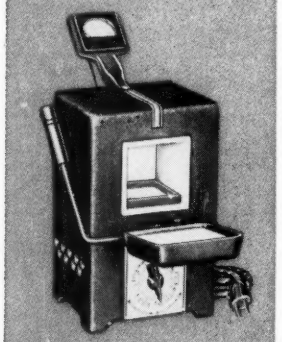

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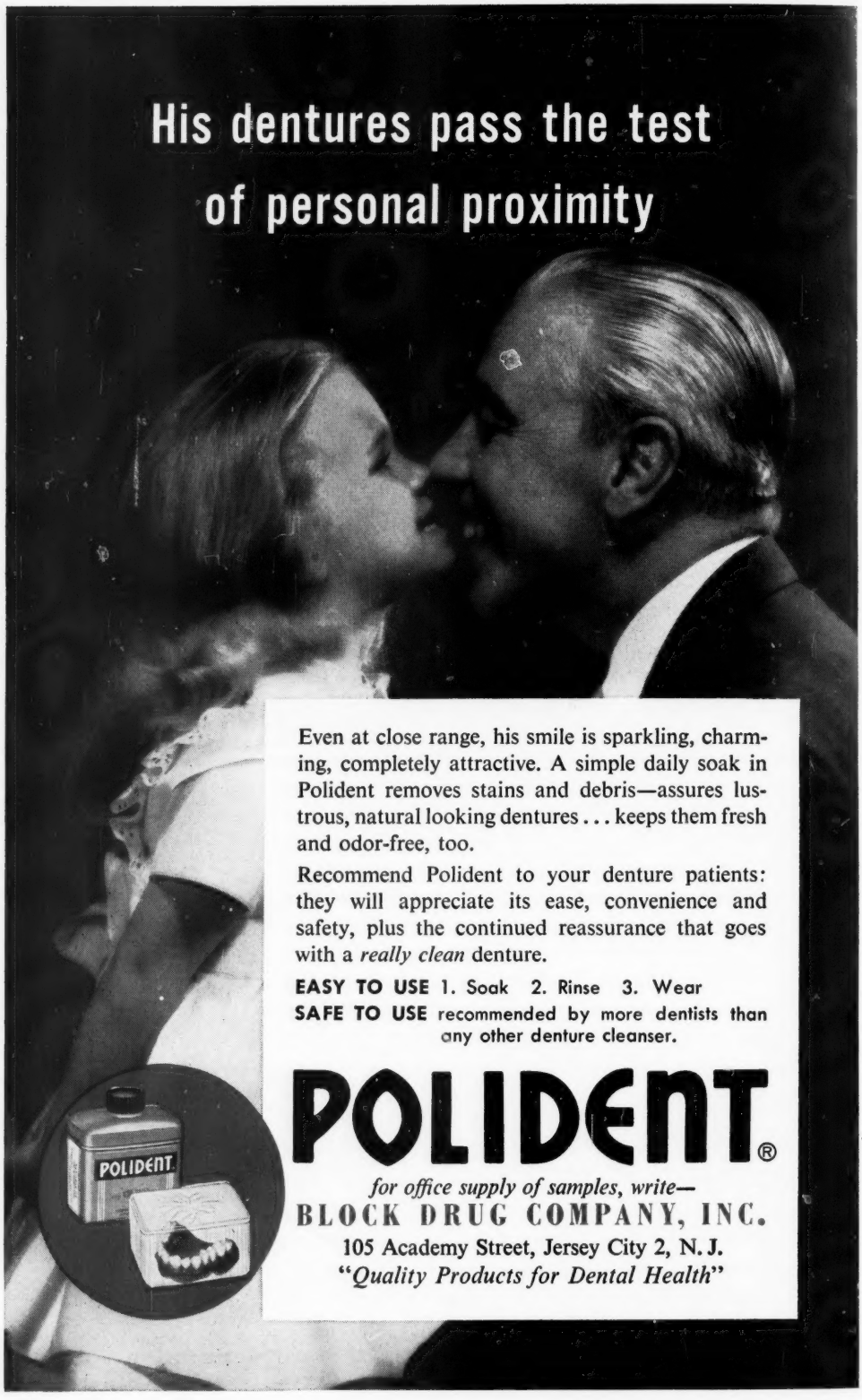

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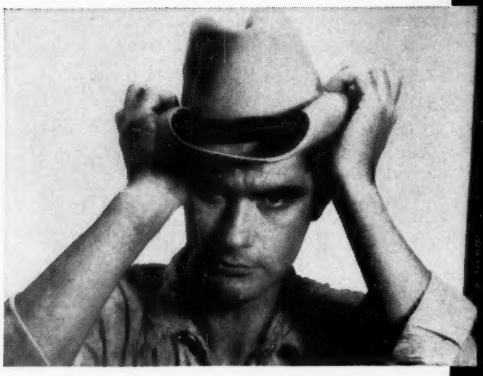

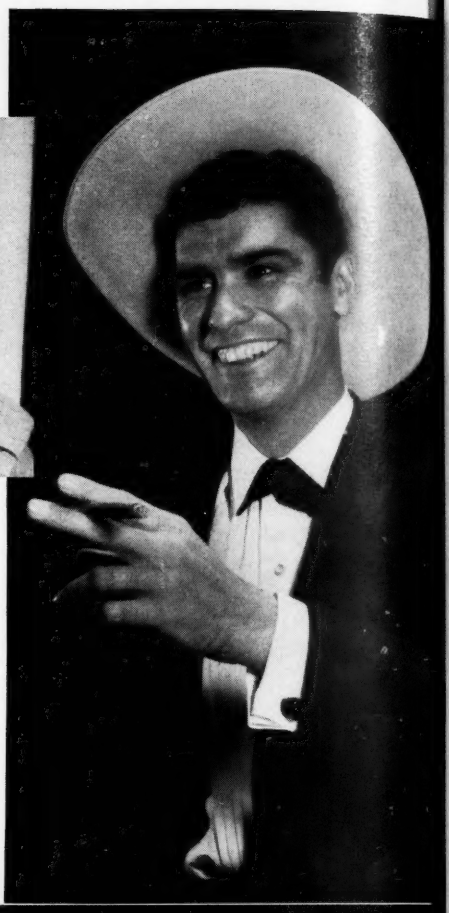

Portfolio of a Young Actor...

This young actor is a complete denture patient. His livelihood depends on the naturalness of his "close-up" smile...

THE JOURNAL OF
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DENTISTRY

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FEBRUARY
1961
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THROUGH THE EYES OF THE EDITOR

Arthur W. Schultz discusses the diagnosis and treatment of patients who have abnormal denture problems. He emphasizes the importance of a thorough diagnosis and extends the diagnostic period through the second phase of his treatment. The suggestion of making "lend dentures" is unique. They provide an opportunity to eliminate many difficulties and complaints before the final dentures are completed. The use of metal bases in the final dentures has many advantages.

Robert G. Vig discusses the appearance phase of denture construction. He points out the things that produce the "denture look" and suggests a physiologic approach as a means for avoiding it. Proper support for the soft tissues around the mouth can be provided by correctly placed teeth and adequate denture base thickness. These objectives can be achieved if the contour of the base and the positions of the teeth duplicate the conditions existing before the teeth were lost.

George A. Hughes and Carl P. Regli propose a new definition of centric relation. It is based upon the observation that some patients can make Gothic arch tracings with sharp apices, even with the mandible slightly protruded. They suggest that in these instances, the centric occlusion should *not* be established with the mandible in the most posterior relationship to the maxillae. The tracings are used for the diagnosis of "abnormal" temporomandibular joint situations. The concept is worthy of further study before it is accepted or rejected. The definition of centric relation they propose differs from other definitions. It involves an application of a certain technique in order to specify the relationships. Other definitions of centric relation are made specific by anatomic, physiologic, or physical considerations. This fresh approach to one of the most important factors in denture construction is stimulating.

Louis J. Boucher reports his experiments to determine whether or not the temporomandibular and capsular ligaments stop the posterior movement of the condyles. He found no difference in Gothic arch (needle point) tracings made before and after these ligaments on fresh human cadaver material were severed. He made similar observations on 27 living patients and found no lateral deviation of the mandible resulting from unilateral severing of these ligaments. He suggests that further study of this problem is indicated.

Masakata Yasaki discusses the relationship between the height of the occlusion rim and the interocclusal distance. He recognizes three different physiologic rest positions which may exist in some patients. This is a different concept of physiologic rest position as it is applied to the procedures involved in establishing jaw relations. Further investigation should be carried out to check the validity of the concept. There can be little doubt that intraoral or extraoral devices attached to occlusion rims may affect certain jaw relation records. His technique conforms to his concept of the factors involved in the recording of the vertical dimension of occlusion.

Lawrence A. Weinberg discusses the orientation of casts on articulators and points out the effects of errors in mounting on the inclinations of the cusps of teeth. He concludes that it is not necessary to use a kinematic (hinge-bow) type of face-bow and that a failure to use a face-bow produces significant errors in occlusion. His analysis seems to indicate approximate location of the hinge axis is adequate (but necessary) for complete dentures.

Ulf Posselt and Per Nevstedt report their investigations of the variations in condyle path inclinations. In 101 patients, the variations were significant when the Dentatus articulator was adjusted by means of wax interocclusal records. They recognize various possible sources of errors in the method used, but making allowance for these errors, the variations cannot be ignored. A study of this type, in which a very soft recording medium that will set hard is used, would be worth while. Plaster of Paris or a zinc oxide and eugenol paste could supply additional data.

Finn Tengs Christensen discusses the effect of the incisal guidance on the inclination of cusps of teeth on dentures. He suggests a formula for determining the cuspal inclination and compares it with formulae proposed by Gysi and Swenson. He concludes that if balanced occlusion is to be obtained with zero degree teeth, the entire composite occlusal surface of all of the teeth on the denture should be considered as a *single* protrusive facet. This seems logical and suggests that an appropriate compensating curve would meet this requirement.

M. B. Sosin compares the support of natural teeth and artificial teeth and suggests a new posterior tooth form which he feels will reduce the force required for mastication of food. The teeth have sharp cutting blades of metal. They reduce the area of surface contact and provide adequate escape ways for food. The tables against which the teeth work are individually designed. The chief disadvantage seems to be their unesthetic appearance.

Allen A. Brewer and Donald C. Hudson report their studies of the contacts between teeth during mastication as well as those occurring at other times. They made use of miniature electronic devices that had been developed in connection with space exploration. This equipment seems to have almost unlimited possibilities for further research. In the pilot study, they found that many contacts between the teeth were made while the patients were chewing most foods and that the contacts were made in both the centric and eccentric occlusal positions. These results are different from most of those obtained by the use of other methods.

Chester Perry discusses diets and nutrition for elderly denture patients. A diet which will supply adequate amounts of proteins, vitamins, and minerals may be difficult for these patients because of tissue tenderness and a lowered pain threshold. Dietary supplements are available and may be prescribed to make certain adequate nutrition of these people. The physician's assistance should be invited, but if he does not recognize the problem, the dentist should supply the necessary guidance.

Joseph S. Landa continues his discussion of the diagnosis and treatment of the causes of denture difficulties. He recognizes that certain difficulties cannot be eliminated by "adjusting" the dentures. In this article, he points out the types of errors that can be corrected only by remaking the dentures. The dentures must not interfere with the normal functions of the tissues surrounding them.

Harold M. Kramer describes his technique for making removable partial dentures. The two phase impression technique provides relief for the abutment teeth by placing a greater part of the occlusal load on the edentulous areas of the ridge. Thus, the denture base is made to fit the soft tissues when they are at rest, and the entire denture is made to be correctly related to the remaining teeth when the denture is under occlusal stress. Apparently, judgment is required when the pressure difference is built into the impression. Otherwise, destructive forces might be exerted on the ridges or teeth. Since he uses internal attachments for retention, this is minimized.

R. H. Killebrew describes his technique for repairing an abutment tooth under a partial denture clasp. An acrylic resin shell is made in an impression of the tooth after the tooth has been restored to contour with wax. After the tooth is prepared for full coverage, the shell is used as a matrix for making the impression. The partial denture is placed in position in the mouth in order to orient the shell correctly on the tooth. The procedure seems to be simple and practical.

Edwin S. Smyd discusses prosthodontic failures resulting from torque, torsion, and bending of dental restorations. His simple illustrations demonstrate the way in which these destructive changes do their damage. Restorations must be designed so the materials from which they are made can with-

stand the forces applied against them. It should be obvious that the problem is not one of simply filling spaces. The restorations must be strong enough and rigid enough to prevent unnecessary stress on the cement, the clasps, the connectors, and the abutment teeth.

Grant E. Overby describes his technique for splinting together teeth with weak periodontal support. It involves using sleeves cemented into teeth and pins cemented into the sleeves. The pins are connected by a cast bar. There are advantages of this method over some others.

Jerome M. Schweitzer urges a conservative approach to oral rehabilitation. This is a timely article since the high speed tooth-cutting techniques can influence dentists to remove more tooth structure than is necessary. However, a difficult decision is involved. It is not easy to determine when teeth should be restored to conform to an existing occlusion (or malocclusion) rather than to "correct" all of the malocclusion. Good judgment is necessary to arrive at the proper decision.

Leo Talkov suggests that study casts be made after all of the teeth are prepared for complete mouth rehabilitation. The study casts are mounted on an articulator, and the preparations are surveyed to check the parallelism of the preparations before the final impressions are made. This procedure would make it possible to detect errors in alignment and to correct them before the wax-up procedures are started. The technique can be adapted to smaller restorations with benefits to both the patient and the dentist.

Milton Silver, Michael C. Howard, and George Klein discuss the indications for porcelain baked on metal restorations. They describe the technique for the preparation of teeth, the essential laboratory procedures, and the technique of cementation. They also point out the possible causes of failures. It is apparent that porcelain baked on gold provides a stronger restoration than porcelain used alone. However, the technique is exacting in all of its phases. The necessity for an adequate bulk of porcelain at the gingival margins might weaken the tooth to be restored beyond the safety point, and the bulk required for strength and color can cause tapered teeth to be restored with crowns having a square outline form. This can lead to poor appearance and damage to the gingival tissue. Unless the technique is carried out with the utmost care, the end result can be somewhat less than is desired. When the conditions in the mouth are favorable, this type of restoration can be effective, but there are situations where other methods would produce better results.

George T. Cowger describes a unique technique for making class V porcelain inlays. A pure gold casting is used as a matrix instead of the usual platinum foil matrix. The procedure eliminates the inaccuracy of fit produced by the removal of the platinum matrix from a completed inlay. Thus, it should reduce the size of the cement line which has characterized many porcelain inlays.

Takao Fusayama, Hiroyasu Hosoda, and V. M. Kher report their tests to determine the effects of clinical variables on the properties of cristobalite investment. Their results indicate that the material permits some limited variation in its handling without seriously impairing the castings, but that changes beyond these limits cause failures. If the results of the various tests are studied, an optimum technique can be developed.

Richard W. Henry and Ralph W. Phillips studied the effect of particle size on the ability of artificial stone to reproduce the line detail in impressions made in elastic materials. All were found to be deficient, but the smaller particle sizes produced the best results.

John B. Boyd, Jr., and David F. Mitchell report their study of the irritation caused by dental cements. Even though the cements were used in a manner different than used for cementation of restorations in teeth, the results indicate some cements cause more irritation than others.

Oscar E. Beder discusses the development of the treatment plan for cleft palate patients. He suggests a team approach with all of the specialties concerned contributing to the final treatment plan. This would assure the patient of the best possible course of treatment. The prosthodontic phase of treatment must be developed to coordinate with that by other specialties, and theirs must be coordinated with prosthetic treatment so patients have the best care.

Mohammad Mazaheri suggests the use of complete dentures over natural teeth of cleft palate patients when the lateral and vertical growth is insufficient. This treatment should be used only where it is indicated and where the remaining teeth are adequately protected. If the maxillae have not reached their full natural growth, such an appliance will restrict further growth. In any instance, the copings covering the natural teeth are essential to success. Where this treatment is indicated, it can do much to assist the cleft palate patient.

—Carl O. Boucher

COMPLETE DENTURES

MANAGEMENT OF DIFFICULT DENTURE PATIENTS

ARTHUR W. SCHULTZ, D.D.S.*
University of California, Extension Division, Los Angeles, Calif.

INDIVIDUALS WHO present uncommon and abnormal denture problems require unusual and resourceful treatment. Because of the extreme complexity of their symptoms and their physical and emotional handicaps, these are difficult denture patients.

Symptoms manifested by these people may be systemic in origin, may be due to psychogenic or anatomic abnormalities, or may be caused by neurologic defects.

Systemic illnesses such as endocrine dysfunctions, hypertension, allergies, or anemias manifest themselves in the oral tissues. They lower the pain threshold and affect the general health of the mucosa so that it is easily injured and is slow to heal.

Functional illness may be responsible for such psychogenic abnormalities as obscure pains or facial spasms, which may or may not be triggered by the presence of dentures in the mouth. Claustrophobia, photophobia, food fadism, gagging, choking, loss of taste, and nausea are other examples of possible psychogenic abnormalities. The attitude and temperament of the patient, together with restrictive patient demands, are symptoms which often reveal severe psychogenic disturbances.

Anatomic abnormalities such as unusual maxillomandibular relationships and jaw movements are frequently presented by difficult denture patients. They may have unusually large tongues, large tuberosities, tori, minimal ridges, pendulous ridges, or the anatomic irregularities caused by a cleft palate, surgical operation, or losses due to accident or heredity.

Neurologic damage resulting from surgical procedures or damage to nerve trunks caused by the degenerative diseases, most often found in senile individuals, also complicates the prosthetic problem.

LIMITATIONS

Each problem patient presents his own peculiar limitations to the prosthodontist, and this individual must be evaluated as a complete human being. The

Read before the American Denture Society in New York, N. Y.
*Special Lecturer.

psychogenic, physiologic, environmental, and mechanical factors related to each individual all influence the final result of treatment.

If the optimum result within the restrictions and limitations presented is to be obtained, procedures for each patient must be based upon observations and diagnosis.[1]

A fundamentally sound approach to this complex problem is to divide the denture service into three stages: (1) the preliminary service, (2) the construction of "lend dentures," and (3) the corrective functional refit procedure.

PRELIMINARY SERVICE

In the preliminary phase, we attempt to gather all available information, to establish rapport and win the confidence of the patient, and to prepare the mouth and mind of the patient to receive the dentures it is planned to construct. It is difficult to accomplish all of these things in one or two visits. Therefore, the usual plan includes about five or six visits over a period of several weeks.

Diagnosis.—Examination and exploration are begun by the use of a diagnostic chart[2] to record the findings. The arrangement of the chart encourages a systematic listing of conditions because of its organized outline sequence. In this chart are lines for tabulating the occupation, age, sex, ethnic origin, weight, medical treatments, special diet, and diet analysis; lines for recording the physical state of the patient—blood pressure, heart condition, joint ailments, presence of tonsils, digestive ills, conditions of sinuses, and known allergies; and lines and spaces for tabulating causes for the loss of teeth, the mental classification, the attitude of the patient, and such other important items as may aid in obtaining an accurate, comprehensive evaluation. By careful observation over a period of several visits, we are also constantly gauging the temperament of the patient in all of our investigations.

After the first visit with the patient, we find that the previous dentist and the patient's physician often have knowledge that can be of aid. These individuals usually have valuable information that helps to complete the diagnostic chart. Cooperation with the physician in the treatment of local and systemic disturbances which manifest themselves orally is important for the welfare of the patient. In succeeding visits, we can observe the effects of oral and systemic medication and tabulate these in the case history.

Patient Attitude.—In the investigation of the attitude and temperament of the patient, one day's complete food intake is charted.[3] This is done to evaluate not only the quantity and quality of the nutrient factors which a patient ingests, but also his notional attitudes in regard to foods. Some patients have prejudices against various foods, such as dairy products, because they either have insufficient or faulty information regarding their value or think they may be harmful. For example, lamb and veal are flesh of immature animals and therefore are avoided by some patients.

By questioning the patient directly about his preferences in regard to the color, shape, and arrangement of the front teeth, we elicit from him emotional reactions and esthetic attitudes. By stimulating a discussion on this subject, his preferences aid us to classify him as phlegmatic, exacting, or neurotic. This, too, substantiates or amends the evaluation of his temperament and guides us in patient management procedures.

Treatment Relining.—Patients who have tender areas or general discomfort and are unable to chew food properly are gratified by the fast relief which can be given them by placement of a temporary soft relining material in the denture at the first visit. Since self-curing resins are available in very soft, medium soft, or hard materials, the one best indicated may be selected. This permits an opportunity to use treatment relining materials long enough to establish comfort and allow for healing of the underlying tissues. This helps to prepare the mouth for the dentures which are to follow.

Cold-curing acrylic resin materials can be used to add extensions on the flange areas which are underextended or help to provide proper contour and better base area coverage. Dentures which have insufficient coverage and underextension can best be corrected by making a new base from an impression which covers the base area adequately. The lower denture is attached to this base with cold-curing resin material, at the correct vertical dimension.

In this preliminary exploratory and treatment series of visits, the patient's mouth is conditioned for dentures a little at a time. By providing comfort in the old dentures of the patient, and perhaps a little added chewing efficiency, we establish confidence and develop a rapport with the patient.

Gagging.—Patients who have a gagging problem can be helped by gradual changes and extensions until the necessary coverage for the denture base has been achieved. If the patient is choked by the lingual extensions of the flanges on the lower denture, we can start with a minimum extension and add a little at a time as tolerance increases.

By such gradual conditioning of the patient, the insight necessary to render successful treatment is gained.

Treatment Dentures.—In patients in whom it is not possible to achieve all of the results desired by changes in the old dentures, we sometimes make temporary treatment dentures in this preliminary phase. These are used for an indefinite time for the purpose of conditioning and preparing the mouth to receive the final dentures.

The use of "bite" splints and occlusal pivots[4] has merit in this preliminary stage. They are used to provide relief from pain in the temporomandibular joints or the muscles of mastication,[5] and sometimes they seem to improve partially lost hearing. Often bruxism can be controlled by the use of a bite splint which is fabricated to fit over the teeth of the lower denture.

Consultation.—The use of prosthetic consultation[6] service has great value with exceptionally difficult problem patients. Consultation is especially important to justify the procedure to be used when it is unusual. It is always advisable to call in a prosthetic consultant if other than an acceptable standard procedure is indicated or planned.

In this preliminary treatment stage, we may uncover notions and attitudes and demands which are not according to accepted procedure. In these instances, it is expedient to construct dentures according to the accepted procedure and then, in addition, to construct a denture or dentures which satisfy the dictates of the patient. All of this can be determined during the preliminary stage. One denture

may be used for its comfort or its esthetic features, and used for that purpose only, and the other when chewing is necessary. Whenever it is impossible to incorporate into one denture all of the desired results, it is advisable to build two dentures.

In this sequence of several visits in the preliminary treatment stage, we also have the opportunity of discontinuing further treatment if we feel that it is impossible to achieve the desired results. We sometimes come to the conclusion with the cooperation and advice of the physician and/or consultant that whatever service we render must be temporary and that it is advisable not to proceed with final dentures until the patient's health and mouth condition become stabilized.

SECOND STAGE: "LEND DENTURES"

With the information obtained in the preliminary service, when the tissues of the mouth have become properly conditioned and when it is felt that the patient has been prepared emotionally to accept them, we are ready to construct functionally correct dentures for the difficult patient. In addition, the patient may also be furnished with another denture at this time which may satisfy a peculiar esthetic or functional need based upon observations made during the preliminary stage. It should be emphasized that this service for the patient supplements the construction of properly made dentures and is generally offered with the concurring recommendation of a consultant.

The dentures to be constructed at this time are labeled "lend dentures" because we want the patient to understand that these are not complete or finished. This allows the prosthodontist the opportunity to make adjustments, render additional treatment, or condition the tissues of the mouth as indicated. It has been my experience that a patient will accept with more active cooperation the task of adaptation to these new dentures if he expects additional adjustments and knows that the work is not completed.

When reasonable comfort has been established and the treatment period has produced healthy, well-healed oral tissues, the patient has become accustomed to the "lend dentures" and is ready for the final procedure.

CORRECTIVE FUNCTIONAL REFIT OF THE LOWER DENTURE

In order to build a corrective functional refit impression,[7] place wax which flows under pressure at mouth temperature in the lower base and have the patient chew gum for an hour or two. This provides a functional adaptation of the denture to the basal seat area. In addition, record an accurate, functionally adapted border on the impression.

This corrective functional refit is used because after new dentures have been used for a month or 6 weeks, the tissues in the mouth undergo many changes. These are compensated for with this functional refit impression in the tissue side of the lower denture. This procedure also serves to correct many other errors and changes that may have occurred in the processing of the dentures, and it also reestablishes the proper occlusion and centric relation.

In every problem denture situation, we routinely use metal lining for the final adaptation in the lower denture[7] to complete the service. There are many advantages

in the use of a metal rather than acrylic resin base in contact with the tissues. Metal bases provide accuracy of fit and lasting durability without warpage and shrinkage. Metal bases are also well tolerated by sensitive tissues.

SUMMARY

A denture service for the management of the difficult denture patient is suggested. The service consists of three parts: the preliminary service, the construction of "lend dentures," and the corrective functional refit of the lower denture.

In the preliminary stage, there is an opportunity to become thoroughly familiarized with the patient. We gain an insight into his emotions and tolerances, establish a rapport with the patient, and gain his confidence. We may, for reasons which become apparent during this period, decide not to make final dentures for this patient at this time.

By providing "lend dentures" for the patient, many hazards that follow the insertion of "completed" dentures are avoided.

The corrective functional refit of the lower denture provides a refinement in dentures to which the patient has already become accustomed. This three stage procedure helps to provide an adequate service for the difficult denture patient.

REFERENCE

1. House, M. M.: The Relationship of Oral Examination to Dental Diagnosis, J. Pros. Den. **8**:208-219, 1958.
2. Thompson, M. J.: Diagnostic Chart of the Odontic Seminar, 1939.
3. Meigs, A.: Personal communication.
4. Sears, V. H.: Occlusal Pivots, J. Pros. Den. **6**:332-338 1956.
5. Schwartz, L.: Disorders of the Temporomandibular Joint, Philadelphia, 1959, W. B. Saunders Company.
6. Regan, L. J.: Doctor and Patient and the Law, St. Louis, 1956, The C. V. Mosby Company, p. 543.
7. Schultz, A. W.: Comfort and Chewing Efficiency in Dentures, J. Pros. Den. **1**:38-48, 1951.

3751 Stocker St.
Los Angeles 8, Calif.

THE DENTURE LOOK

ROBERT G. VIG, D.D.S.*
Inglewood, Calif.

THE DENTURE LOOK is "that typical facial appearance common to most denture wearers." This article will attempt to analyze the various causative factors, suggesting remedial measures largely by inference only.

PATIENT EDUCATION

Pictures and illustrations of dentures have remained relatively unchanged for the past 100 years. Therefore, the patient naturally expects his dentures to look precisely this way. All contact with artificial teeth, prior to his own experience, has fixed in his mind the classic image wherein small, youthful teeth are arranged symmetrically in the typical manner. The prosthodontist who does not choose to perpetuate the denture look must be prepared to educate his patients to accept dentures which promote harmony between the denture prostheses and the other facial structures.

Most prospective denture patients have anterior teeth which leave something to be desired in appearance. Usually, these individuals think that these blemishes will be corrected when they receive artificial teeth. They are unaware of what will happen to their facial appearance if the individual characteristics of the anterior teeth are lost and replaced by a "conventional" denture.

TOOTH PLACEMENT

Tooth placement is very likely the greatest contributor to the denture look. As was taught in dental schools until very recently, tooth placement was not a matter of choice but was accomplished by placing the maxillary anterior teeth as close to the ridge crest as possible. This tooth position was used because it was considered to be the only "mechanically" sound placement that would promote denture stability. Hooper,[1] as long ago as 1927, called attention to this fallacy when he admonished, "Disregard the age old rule of placing the teeth over the ridge." Pound[2] advises placing the teeth ". . . back in the original position from which they came." A great many others have accepted this philosophy, and it is widely advocated in modern prosthodontic literature.

Biomechanics is the word combination which is used to justify many purely mechanical concepts. However, too often "bio" and "mechanical" are incompatible,

*Assistant Professor, Prosthetic Department, University of Southern California, School of Dentistry, Los Angeles, Calif.

especially where the mechanical aspect is emphasized and the biologic is rationalized into being. When prosthodontic procedures are performed as dictated by physiologic considerations, the mechanical aspects take care of themselves. Since the mechanical placement of teeth over the residual ridge crests automatically ensures the denture look, it is high time to discard it forever.

The method of Fisher[3] of creating the anterior composition is the most certain way of placing the teeth to avoid the denture look. Each anterior tooth is placed in the trial base, tested phonetically in the patient's mouth for position, and examined critically as to esthetic appearance. The appearance of the soft tissues also is determined. The lip support is altered by the labiolingual position and the axial inclination of the anterior teeth. Since we cannot arrange the artificial teeth precisely where the natural teeth were in relation to the lips without the aid of preextraction records, this must be a procedure accomplished with the patient in the dental office.

TABLE I. INCISAL EDGE EXPOSURE

LIP CLASS	NO. OF CASES	NO. OF CASES 1 TO 2 MM.	RANGE	AVERAGE
Normal	39	9	0–6	2.73
Heavy	32	14	0–5	1.47
Protrusive	26	9	0–7	3.04
Short	36	9	1–7	3.61
Total	133	41	0–7	2.72

VERTICAL POSITION

The vertical position of the anterior teeth also adds to or detracts from the denture look. Prothero,[4] Nichols,[5] Sears,[6] Landa,[7] Schlosser and Gehl,[8] and Allen[9] all instruct us to position the upper central incisor vertically so that 0 to 2 mm. of the incisal edge is visible below the upper lip. Some of these authors suggest that the very old and very young may be exceptions and that modification may be necessary. A survey conducted at the University of Southern California* disclosed that these figures were somewhat misleading. One hundred and thirty-three dentulous subjects were chosen at random and examined. Their lip types were classified as normal, heavy, protrusive, or short. The range and average were found within each group, and the average labial surface exposure was computed for the entire number. This figure was 2.72 mm., and only 41 of the subjects fell within the 1 to 2 mm. of exposure group. Forty-four subjects displayed from 4 to 7 mm. of the labial surfaces with the upper lip at rest. This group would suffer the most drastically from the denture look when given dentures with 1 to 2 mm. of the maxillary central incisors displayed. Table I summarizes the findings of this survey.

*Unpublished data, 1956.

It is easily seen how the placement of the upper anterior teeth according to a preconceived position, rather than to the one position suitable for the patient, will make everyone tend to look the same. This is contrary to Nature, which gives each person an individualistic appearance.

POSTERIOR TOOTH PLACEMENT

The upper posterior teeth are also culpable in contributing to the denture look. The immediate recession of the visable posterior teeth distal to the cuspids does not produce a natural effect. To place the bicuspids and molars where they can be seen shifts them to the buccal slope of the ridge. Tench[10] embraces the concept that the teeth must be placed between the functioning muscles of the tongue, lips, and cheeks. Placement to the contrary handicaps these essential organs of mastication and speech. Thus, we have not only an esthetic reason but a physiologic one for placing the posterior teeth back where they came from.

IMMEDIATE DENTURE ESTHETICS

The esthetic result of an immediate denture is certain if the natural teeth are replaced precisely by the artificial ones. The tooth positioning in immediate dentures is out of our hands, hence not subject to our ideas and concepts of tooth arrangement. Whenever we attempt to modify an immediate denture setup, we invariably do so in the direction of the "average" or "ideal" composition. When left intact, tooth arrangements which were so grossly atypical and ugly on the casts appear normal and somehow suitable in the patient's mouth.

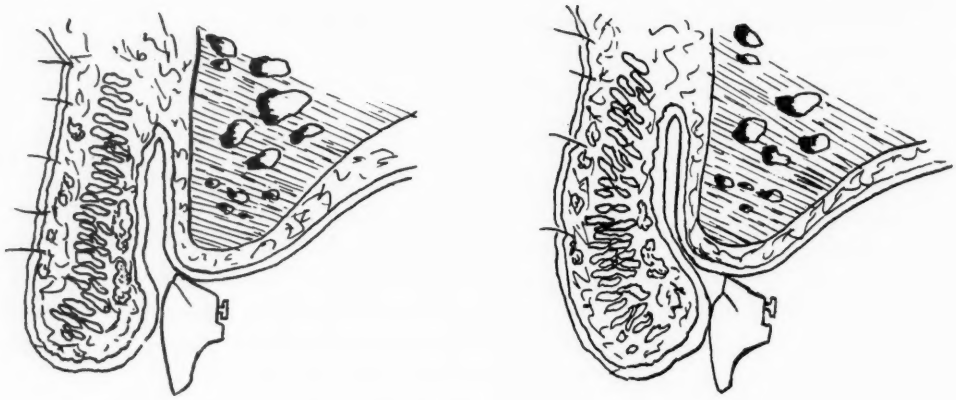
There are certain lessons that we can learn from this observation on immediate denture esthetics. These are: (1) natural tooth *positions* are esthetic, (2) natural tooth *postures* are esthetic, (3) natural tooth *contours* are esthetic, (4) natural tooth *blemishes,* within limits, are esthetic, (5) asymmetry is normal, and (6) the classic concept of tooth arrangement and position bears small relation to the realities of Nature.

Proper lip support is produced by the labial flanges and the gingival two-thirds of the anterior teeth. Attempts are made frequently to plump out the lips by thickening the denture base when placement of the teeth over the ridge has caused the sunken profile of the denture look. An inevitable and uncosmetic failure occurs when this is done. The lip is inverted and an oval profile results which has no counterpart in Nature (Fig. 1).

Some dentists attempt to accomplish alterations in the horizontal ridge relations. When a retruded relationship exists, the dentures are constructed with the maxillary anterior teeth set lingually and the mandibular anterior teeth set labially so that the upper and lower teeth meet in an "ideal" relationship. A similar "ideal" relationship is developed for mandibular prognathism. Again, this type of treatment represents an attempt to make every one look like an "ideal." Actually, it results in the denture look, plus discomfort and malfunction.

TOOTH ARRANGEMENT

Pound,[2] Frush and Fisher,[11] and others have attempted to sway dentists away from the classic concepts that dominate denture esthetics. Arrangement of the



A. *B.*

Fig. 1.—*A*, The lip receives proper support by a correctly placed labial surface of the artificial tooth. *B*, The lack of support by the incorrectly placed artificial tooth causes a convex lip profile with virtual disappearance of the vermilion border.

teeth in the classic manner, as far as axial inclination and relation to the occlusal plane are concerned, may produce an esthetic result for the very young individual. However, we are rarely asked to construct dentures for this age group. Any consistent arrangement pattern tends to make all patients look alike.

The factors of sex, personality, and age in anterior tooth arrangements have been discussed by Frush and Fisher.[11] Others are successful in creating an individualistic appearance of the patient's teeth in harmony with the rest of his appearance by other methods. The results are the important consideration. However, if the dentist is not highly artistic, he will benefit from a definite interpretation of the sex, personality, and age factors.

Failure of the incisal edges of the upper anterior teeth to follow the curve of the lower lip is another heavy contributor to the denture look. When the tooth row crosses the mouth opening from commissure to commissure in a straight line, Nature's manner has been contradicted. The incisal line of the lower anterior teeth should usually give the impression that the central incisors are the zenith of a slight curve descending toward the corners of the mouth.

TOOTH SELECTION

Selection of the teeth is often a knotty problem. The typal system of Williams[12] has been modified by House[13] and the problem thereby greatly simplified. However, since this method of selecting the outline form of the tooth is wrong about as often as it is right, we must be alert to abandon this scheme and to use the teeth that seem to be correct for the patient. Wright observed that lack of harmony between face form and tooth outline form does not appear incongruous or unesthetic. However, he did feel that the exceptions did not necessarily rule out the use of the system which harmonizes face and tooth form, since it is a "simple and esthetically sound practice." Artistic sense and good judgment are excellent adjuncts to any system of tooth selection.

Most dentists use the manufacturers' carded sets of artificial teeth without modification. This practice breeds monotonous dentures. It is usually necessary to "mix up" anterior teeth in order to avoid the denture look. Central incisors were measured by Black and Krajicek, and they did not find any measuring less than 8 mm. in width. The fact that many dentures are made using upper central incisors that are less than 8 mm. in width is another cause of the denture look.

TOOTH SHADE

Color selection is also a problem. It is occasionally necessary to mix shades of anterior teeth to avoid an artificial appearance. Often, there are as many as four completely different shades of teeth in the same mouth. Yet, most artificial teeth are selected in one shade only. DeVan[14] suggests interspersing plastic teeth with the porcelain teeth, since their color characteristics of hue, brilliance, and saturation are slightly different. Use of a darker tooth can create a useful illusion of an endodontically involved tooth.

The presence of a row of uniformly light teeth surrounded by aging skin is incongruous and unnecessary. This facet of the denture look can be removed with little effort, and with good harmonious tooth colors available, such practices can no longer be excused.

MODIFICATION OF ARTIFICIAL TEETH

The denture look features teeth untouched by the passage of time. Curvaceous proximal surfaces and softly rounded incisal edges appear false in the mouths of older patients. The brilliant reflections from the highly glazed labial surfaces of most teeth are in sharp contrast to the dulled enamel of middle and old age and overemphasize the teeth involved. This may cause the patient to insist on a smaller mold of tooth than is really indicated and, thus, produce the denture look.

A chipped incisal edge of a lateral incisor often detracts from the artificiality of a denture. A similar effect is gained by altering the teeth with stones and disks. The lack of abrasion on the proximal surfaces leaves interproximal contacts small. The contact area also is too near the labial surface to look correct in most instances. Flattening of the contact area and grinding to give the illusion of greater tooth depth will correct these errors.

The presence of sharply pointed cusps on cuspids or biscuspids can unmask a denture if the age group of the wearer renders sharp-pointed cusps unlikely. Broadening and flattening cusp tips also reduce the translucency of the tooth in this area. Excessive translucency is also an obvious artificiality in the unground incisal edges of the central and lateral incisors of both dental arches.

The placement of restorations or stains causes a resemblance to a well cared for mouth, but disfiguring restorations with badly executed margins or stains, which do not closely resemble their counterparts in the natural dentition, do very little to detract from the denture look. The former procedures are also needed in the posterior teeth where the departure from the denture look is more subtle, yet extremely effective.

RESTORING CORRECT FACE LENGTH

When the average denture patient closes the teeth into centric occlusion, the lower one-third of his face becomes less than one-third of the facial length, and the illusion of natural teeth is lost. This disproportion is not always amenable to change, as the occlusal vertical dimension must under no circumstances intrude upon the interocclusal distance.

Since no real physical damage can be done by reducing the vertical dimension of occlusion, it has been taught that if we should err, it should be on the short side. However, an error in establishing vertical dimension is so productive of the denture look that this correction of error will have far-reaching effects. When the vertical dimension of occlusion is established by a combination of methods, it can be arrived at confidently and precisely. When correctly established, this factor is of great assistance in avoiding the denture look.

The reduction of the interridge distance has been cited frequently as a sound denture procedure. The objective is the closer approximation of the occlusal surfaces to the basal seats, thereby reducing the leverage factor. This is a mechanical concept which does not take into consideration the vertical position of the food table in relation to the tongue and buccinator muscles. Similarly, the vertical dimension of occlusion is shortened sometimes to reduce muscular forces. The rationale is that since the closing muscles will be required to function at less than their optimal length, their power will be curbed to prevent a greater force than the supporting tissues can tolerate. This philosophy resembles an attempt to control the power of a horse by cutting off one of his legs rather than by putting a bit in his bridle.

Terrell[15] feels that our responsibilty to the patient is a continuing one. We should not insert dentures in the patient's mouth and dismiss him forever. Natural atrophic processes occur, though at vastly different paces, in all denture patients. This results in a loss of vertical dimension with occlusal trauma adding to and compounding the difficulties of the situation. Relining of the dentures at the proper time will restore the correct facial dimensions and erase the denture look.

DENTURE BASE CONSIDERATIONS

The denture base was a major appearance problem in the era of vulcanite. With more lifelike materials available to simulate the gingival and oral mucosa, one would expect that the antiquated base sculpture would disappear. However, a critical look at a typical denture, comparing it to a cast of a dentulous mouth, shows that this is not always true. Since the conformation and color of the interdental papillae are expressive of the age and pigmentation of the patient, the interseptal resin of the base should be formed and colored with great care. The outline form of the teeth may also be modified by the treatment of the base to produce a complimentary effect to the other facial characteristics. French[16] demonstrated that modifications of outline form are possible by changes in the resin matrix.

The color of the visible matrix (denture base) should duplicate the natural colors as closely as possible. In addition, the light reflective qualities should be similar and the surface details of texture and anatomic condition reproduced to as great an extent as the limitations in materials and our artistic sense will permit.

COMFORT AND CONFIDENCE

Comfort is the number one objective of complete denture patients. However, in an intricate manner, good appearance is so related psychologically to comfort that the two cannot be separated. Confidence in the ability of the denture to remain in place and to deceive people is in turn all bound up with good appearance. Occlusal problems or inadequate bases may cause discomfort or lack of confidence as well. We can demonstrate that all factors involved in denture construction are so interrelated that neglect of any one factor will probably result in the denture look.

AGING

The aging changes which are normal must not be disregarded.[17] The restoration of facial contours beyond compatability with the physiologic age of the patient produces a strange appearance which calls attention to his dentures. Since the lip becomes thinner with senile atrophy, it is less everted and tends to display a thinner vermilion border. Thus, an attempt to create a more youthful appearance will appear inharmonious with the skin and facial structures and will produce a displacing factor in that the denture will be out of balance between the tongue and labial musculature.

CONCLUSION

The best manner to avoid the denture look is a physiologic approach to denture service. The personal satisfaction to the prosthodontist and the psychologic stimulation to the patients make the mastery of the necessary details most worth while.

REFERENCES

1. Hooper, B. L.: Prosthodontia as a Fine Art, D. Digest **33**:691-703, 767-788, 1927.
2. Pound, E.: Lost—Fine Arts in the Fallacy of the Ridges, J. Pros. Den. **4**:6-16, 1954.
3. Fisher, R. D.: Personal communication.
4. Prothero, J. H.: Prosthetic Dentistry, ed. 4, Chicago, 1928, Medical-Dental Publishing Co., p. 692.
5. Nichols, I. G.: Prosthetic Dentistry, St. Louis, 1930, The C. V. Mosby Company, p. 170.
6. Sears, V. H.: Principles and Technics for Complete Denture Construction, St. Louis, 1949, The C. V. Mosby Company, p. 243.
7. Landa, J. S.: Practical Full Denture Prosthesis, ed. 2, Brooklyn, 1954, Dental Items of Interest Publishing Co., p. 138.
8. Schlosser, R. O., and Gehl, D. H.: Complete Denture Prosthesis, ed. 3, Philadelphia, 1953, W. B. Saunders Company, pp. 196-197.
9. Allen, A. G.: Goebells' Prosthetic Dentistry, ed. 2, London, 1936, Oxford University Press, p. 97.
10. Tench, R.: Personal communication.
11. Frush, J. P., and Fisher, R. D.: Introduction to Dentogenic Restorations, J. Pros. Den. **5**:586-595, 1955.
12. Williams, J. L.: The Esthetic and Anatomical Basis of Dental Prosthesis, D. Digest **24**:264-282, 400-407, 1920.
13. House, M. M.: Art—A Fundamental in Denture Prosthesis, J.A.D.A. **24**:406-422, 1937.
14. DeVan, M. M.: Appearance Phase of Denture Construction, D. Clin. N. America, 1957, pp. 255-268.
15. Terrell, W. H.: Immediate Restorations by Complete Dentures, J. Pros. Den. **1**:496, 1951; Austral. J. Den. **55**:288-297, 1951.
16. French, F. A.: The Selection and Arrangement of the Anterior Teeth in Prosthetic Dentures, J. Pros. Den. **1**:587-593, 1951.
17. Lammie, G. A.: Aging Changes and the Complete Lower Denture, J. Pros. Den. **6**:450-464, 1956.

8112 Second Ave.
Inglewood, Calif

WHAT IS CENTRIC RELATION?

GEORGE A. HUGHES, D.D.S.,* AND CARL P. REGLI, D.D.S.**
University of California, School of Dentistry, San Francisco, Calif.

THE IMPORTANCE OF CENTRIC RELATION in complete denture prosthodontics has been well known for many years. Some dentists claim that a correct centric relation is the most important single measurement made in the construction of complete dentures. This opinion is clearly set forth by Tench,[1] Tuckfield,[2] and Block.[3]

Unfortunately, however, no common agreement has been reached as to what constitutes centric relation or how it is best determined and recorded for all patients. Various terms have been proposed, some accepted for a time and then modified or rejected. The old phrase "taking the bite" gave way to the more nearly correct term "central occlusion." The term "central occlusion" was rectified and two more explicit terms were accepted, namely, "centric relation" and "centric occlusion." Perhaps the term "centric relation" should be rephrased as "centric maxillomandibular relation" so that it would be more definite.[4]

METHODS OF REGISTERING CENTRIC RELATION

Centric relation is generally defined as the "most retruded relation of the mandible to the maxillae when the condyles are in their most posterior unstrained positions in the glenoid fossae from which lateral movement can be made, at any given degree of jaw separation."[5] Many prosthodontists are not in complete accord with this definition. Hence, modifying terms such as "true centric, functional centric, acquired centric, and habitual centric" are used. Some prosthodontists believe that vertical dimension is a part of centric relation,[6,7] while some believe that centric relation should be recorded with zero pressure.[3,8] Others [9,10] recommended that light pressure be used. Silverman[4] insists that heavy stress be exerted while registering centric relation. The proponents of the nonpressure technique invariably incorporate remounting and equilibrating the occlusion after dentures are constructed to compensate for resiliency of tissue under masticating pressure. The proponents of the functional or pressure techniques expect to do little or no correction of the occlusion after delivery of the dentures.

The most commonly recommended method of determining centric relation is the Gothic arch (needle point) tracing proposed by Gysi in 1910.[11] Since that time, the tracing method has been both used and abused. Tench[1] accepted this method as the only reliable way of determining centric relation. Hanau[8] recommended the

Read before the American Dental Association, Dallas, Texas.
*Professor of Denture Prosthesis, Chairman of the Division of Prosthodontics.
**Professor of Denture Prosthesis, Chairman of Denture Prosthesis.

use of the Gothic arch tracing but warned that it was a means of checking mandibular position and should be neither overrated nor underrated. Granger[12] insists that needle point tracing is not a reliable means of determining centric relation, since it is recorded in a horizontal plane only. He believes that centric relation should be considered as a vertical rotational relationship related to the hinge axis. However, most prosthodontists seem to agree with Sears[13] "that some form of tracing device is desirable if we hope to arrange posterior teeth with the required accuracy."

The prosthodontists who use some type of needle point tracing are not in accord regarding the relationship of the stylus to the tracing for determining centric relation. Swaggart[14] wants some freedom of movement. Brill[15] claims that the retruded position of the mandible (stylus at the apex of the tracing) does not coincide with the maximum intercuspation in all persons. Trapozzano[16] insists that the retruded unstrained relation is the only proper position and that this position is constant throughout life. Boos[17] claims that 35 per cent of 400 subjects had their "best" centric position 1 to 7 mm. distal to the apex of the Gothic arch tracing. Brown[18] believes that the needle point tracing is unreliable and recommends repeated closures into wax under close observation. Jamieson[19] recommends an interocclusal record made with the tongue held at the posterior part of the upper baseplate. Mandibular placement with manual pressure by the dentist is recommended by some, but this method is questioned from a physiologic basis by Brill.[15]

Why are there so many opinions and why so much confusion? The calm, reflective attitude by Kingery[7] may be the solution. He states, "The position of the horizontal relationship of the mandible to the maxillae is a positional relationship inherent to each individual." Boos[20] probably comes close to explaining the situation when he states that "in normal cases the occlusion, the temporomandibular joints, the bone, the soft tissue, and the musculature all produce the same relation to each other and any one of the many registration technics can be used."

Unfortunately, no one method of registering centric relation will meet the needs of both normal and abnormal patients. If all patients were normal, we would consider "that centric relation is unique in that its regulation is the one and only mechanical step in denture construction."[21] If this were true, uniformly satisfactory results would be obtained by the use of a Gothic arch tracing with the stylus always set at the apex of the tracing. Unfortunately, some patients do not fit this pattern and must be considered abnormal. Hence, the abnormal must be differentiated from the normal.

EXPLANATION OF GOTHIC ARCH TRACING

A Gothic arch tracing with a sharp apex can only be obtained by a pivoting of the mandible on first one condyle and then the other as right and left lateral movements are made. If the condyles do not pivot or do not have centers from which lateral movements are made, a faulty tracing or one with a rounded apex will be obtained.

Most of the proponents of the needle point tracing method assume that a correct tracing with a sharp apex is indicative of condyles properly situated in their glenoid fossae. Unfortunately, the tracing merely indicates pivoting condyles,

not whether the pivoting occurs in normal, retruded, intruded, or protruded positions in the glenoid fossae. It is hoped that obtaining a tracing under unstrained conditions will prevent an improper location of the condyles.

Many patients have developed faulty condylar positions because of malocclusions, either natural or the result of orthodontic treatment or faulty prosthesis. Because some patients can accommodate the muscular positioning of the mandible by tactile sensations from the teeth and periodontal membranes, the muscles apparently are conditioned away from their normal action. After the natural teeth are extracted, the condyles can assume a faulty position without the patient being conscious of any strain. The Gothic arch tracing certainly can be misleading for these patients unless much care and judgment are used.

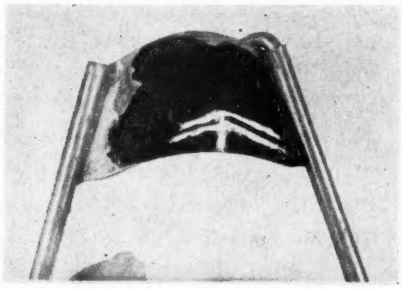


Fig. 1.—The posterior tracing is made from a free closure position. The anterior tracing is made from the generally accepted retruded position of the mandible.

DIFFERENTIATING NORMAL AND ABNORMAL PATIENTS

In order to differentiate the abnormal from the normal patients, some type of an extraoral tracing device is essential. Gothic arch tracing is used as an indicator or aid in observing horizontal mandibular action.

PROCEDURE

The vertical dimension of occlusion is established within close limits as a separate and prerequisite step to determining centric relation. The tracing devices are attached to the occlusion rims and the rims are placed in the mouth. The patient opens and closes the mouth a number of times, and the relation of the stylus to the table which has been coated with a thin layer of black wax is noted. The patient is instructed to make the maximum anteroposterior movement of the mandible to establish the protrusive range. Next, the patient moves the mandible forward, then backward. This procedure is best demonstrated first by the dentist. When the patient has the mandible in a retruded position, he is instructed to move the jaw laterally to either right or left and to stop. The stylus is elevated and the patient is instructed to bring the mandible back to the retruded position. Then, the patient moves the jaw to the opposite side. The relationship at the initial point of contact to the apex of the tracing is observed. It may be necessary to repeat the procedure several times until a sharp, well-defined tracing is achieved.

The stylus is removed and the patient opens the mouth, closes it, swallows several times, and then holds the mandible steady. The stylus is replaced, and the relationship of the point to the apex of the retruded tracing is noted again. Many times the stylus will rest at the apex, and these may be concluded to be normal patients. Sometimes, the stylus will rest distal to the apex of the retruded tracing. When this occurs, the patient is instructed to hold the occlusion rims lightly together and to move the mandible first to one lateral position and then to the other. Frequently, a different Gothic arch tracing can be made. This second tracing may have a greater included angle than the first tracing (the retruded tracing) or it may have the same included angle, i.e., the lateral movements are parallel but two distinct tracings have been recorded (Fig. 1). Both tracings are examined, and if the more distal tracing has a sharp apex, the tracing made with the jaw protruded rather than the conventional tracing with the jaw retruded is used as the preferred registration.

Cephalometric roentgenograms of the temporomandibular joints indicate that during the tracing made with the jaw retruded, many patients of this type have the condyles in the posterior part of the glenoid fossae. When the mandible is positioned with the jaw protruded (distal tracing), the condyles are in the anterior part of the glenoid fossae, which is their normal position.[22]

If the patient rests with the stylus distal to the apex of the Gothic arch tracing but cannot make a well-defined distal tracing with a sharp apex at the resting

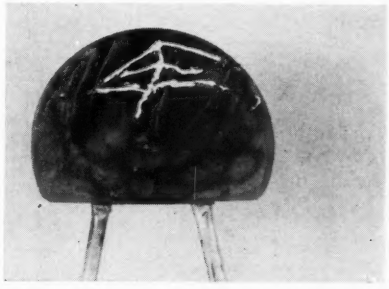


Fig. 2.—The patient was not comfortable at any position anterior to the erratic posterior tracing.

point, the case history should be reviewed. Was the patient without posterior teeth for a period of time and did he learn bad habits of mastication, or did the patient wear a nonfunctioning partial denture which caused the same result? If this has occurred, the sharp tracing made with the jaw retruded is probably the correct centric relation, and an attempt is made to redevelop proper function of the muscles of mastication by one of several methods. We use the House chew-in method most frequently.

Occasionally, the patient cannot make a sharp tracing starting from the point where the stylus contacts the recording table, and it is definitely uncomfortable for him to assume the retruded position. Some patients have to use enough muscular effort to make a tracing with a sharp apex that muscular spasms of the infrahyoid

muscles occur (Fig. 2). For these patients, the Patterson[23] grinding method of developing occlusal curves is used and flat teeth are set to the curves thus developed.

Another type of patient encountered occasionally comes to rest with the stylus not at the apex of the tracing but part way out on one of the lateral paths. Patients of this nature have developed faulty muscular patterns because of cuspal interference of either natural teeth or dentures which were not in proper centric relation. The relationship of the condyles in the fossae is observed with cephalometric roentgenograms. Roentgenograms of the joints at rest position, with the occlusion rims in contact, with the stylus in the relation to the tracing that the patient wishes to

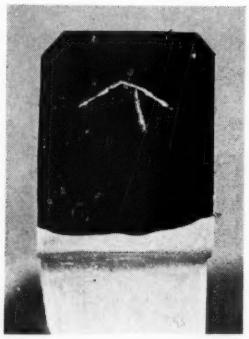


Fig. 3.—The tracing needle is to the right of the tracing apex in the free closure position because of a temporomandibular joint irregularity.

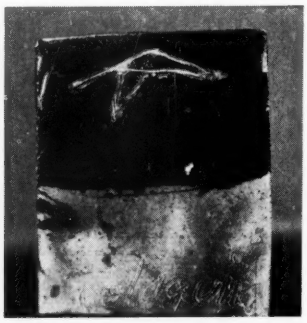


Fig. 4.—The posterior tracing to the left of the anterior tracing was caused by a disharmony between centric occlusion and centric relation of the patient's natural teeth.

assume, and with the stylus at the apex of the Gothic arch tracing, are made. If a posterior relationship of the condyle is noted on one side when the stylus is at the apex of the tracing, an abnormal unilateral condylar position may be suspected. Treatment with splints may be indicated to reposition the condyles in a more favorable location in the glenoid fossae. These patients usually have a history of temporomandibular joint dysfunction (Fig. 3). If an examination of the roentgenograms indicates a favorable relationship of the condyles in the glenoid fossae when the stylus is at the apex of the tracing and a posterior placement of the condyle on the side where the stylus rests to one side of the apex of the tracing, a muscular

imbalance is suspected. These muscular imbalances are frequently caused by faulty centric relations of either natural dentitions or dentures. The apex of the tracing is used as an indication of centric relation for these patients (Fig. 4). The use of splints may be indicated prior to denture construction.

REGISTRATION OF CENTRIC RELATION

After centric relation has been determined, the next problem is to register this relationship so that the casts can be properly mounted on an articulator. There is no method which can be used for all patients. The House chew-in method* registers the maxillomandibular relation under chewing conditions and compensates in part for tissue resiliency. If the ridge conditions will not permit the use of the House chew-in, a central bearing technique with an extraoral tracer is used. The Robinson Equilibrator[24] is recommended in place of the single central bearing stud if denture space permits.

If the patient seems to be absolutely unable to accept the apex of any Gothic arch tracing as centric relation, the Patterson chew-in technique is used to develop occlusal curves. The rims are secured together in the position previously determined. Nonanatomic teeth are set to the curve generated to achieve functional balanced occlusion in all ranges and in almost any relationship of the mandible to the maxillae. Anatomic teeth are recommended for other patients.

SUMMARY

1. The correct centric relation is essential in complete denture construction.

2. Prosthodontists disagree as to what constitutes centric relation and how it is best registered.

3. The present accepted definition of centric relation is based upon the relationships of the mandibular condyles to the glenoid fossae under normal or ideal conditions.

4. The Gothic arch tracing is the best visual device for ascertaining the horizontal relationships of mandibular positions and two dimensional movements.

5. The Gothic arch tracing does not determine centric relation.

6. A sharp Gothic arch tracing may be obtained with the condyles in more than one location in the glenoid fossae.

7. A method is advocated to utilize and analyze Gothic arch tracings in order to determine centric relation.

CONCLUSION

There is no doubt of the importance of centric relation. However, the present definition is misleading. Centric relation may better be defined as "that relation of the mandible to the maxillae when the condyles are in the most protruded or anterior position in the glenoid fossae from which a definite needle point tracing can be made at the correct degree of jaw separation."

*This method is used as a standard procedure in the University of California Denture Clinic.

REFERENCES

1. Tench, R. W.: Interpretation and Registration of Mandibulomaxillary Relations and Their Reproduction in an Instrument, J.A.D.A. **13**:1675, 1926.
2. Tuckfield, W. J.: The Problem of the Mandibular Denture, J. Pros. Den. **3**:8, 1953.
3. Block, L. S.: Common Factors in Complete Denture Prosthetics, J. Pros. Den. **3**:736, 1953.
4. Silverman, M. M.: Centric Occlusion and Jaw Relations and Fallacies of Current Concepts, J. Pros. Den. **7**:750, 1957.
5. Academy of Denture Prosthetics: Glossary of Prosthodontic Terms, ed. 2, J. Pros. Den. **6**:Part Two, pp. 13-14, 1960.
6. Boucher, C. O.: Occlusion in Prosthodontics, J. Pros. Den. **3**:633, 1953.
7. Kingery, R. H.: A Review of Some of the Problems Associated With Centric Relations, J. Pros. Den. **2**:307, 1952.
8. Hanau, R. L.: Dental Engineering, vol. I, Buffalo, 1926, Hanau Engineering Co.
9. Kazis, H.: Functional Aspects of Complete Mouth Rehabilitation, J. Pros. Den. **4**:833, 1954.
10. Trapozzano, V. R.: An Analysis of Current Concepts of Occlusion, J. Pros. Den. **5**:764, 1955.
11. Gysi, A.: The Problem of Articulation, D. Cosmos **52**:1, 1910.
12. Granger, E. R.: Centric Relation, J. Pros. Den. **2**:160, 1952.
13. Sears, V. H.: The Selection and Management of Posterior Teeth, J. Pros. Den. **7**:723, 1957.
14. Swaggart, L. W.: Occlusal Harmony in Complete Denture Construction, J. Pros. Den. **7**:434, 1957.
15. Brill, N.: Reflexes, Registrations, and Prosthetic Therapy, J. Pros. Den. **7**:341, 1957.
16. Trapozzano, V. R.: Occlusal Records, J. Pros. Den. **5**:325, 1955.
17. Boos, R. H.: Occlusion From Rest Position, J. Pros. Den. **2**:575, 1952.
18. Brown, J. C.: Articulator Mechanisms for Inducing Condyle Migration, J. Pros. Den. **4**:208, 1954.
19. Jamieson, C. H.: A Modern Concept of Complete Dentures, J. Pros. Den. **6**:582, 1956.
20. Boos, R. H.: Basic Anatomic Factors of Jaw Position, J. Pros. Den. **4**:200, 1954.
21. Porter, C. G.: Simplicity Versus Complexity, J. Pros. Den. **2**:723, 1952.
22. Swenson, M. G.: Complete Dentures, ed. 3, St. Louis, 1953, The C. V. Mosby Company.
23. Patterson, A. H.: Construction of Artificial Dentures, D. Cosmos **65**:679, 1923.
24. Robinson, S. C.: Equilibrated Functional Occlusion, J. Pros. Den. **2**:462, 1952.

University of California
San Francisco Medical Center
School of Dentistry
San Francisco 22, Calif.

LIMITING FACTORS IN POSTERIOR MOVEMENTS OF MANDIBULAR CONDYLES

LOUIS J. BOUCHER, D.D.S.*
Marquette University, School of Dentistry, Milwaukee, Wis.

APRILE AND SAIZAR[1] found that the symphyseal angle could be traced on human cadavers with the joints intact but with the muscles removed. These findings indicate that the muscles are not responsible for limiting the posterior movements of the mandible. Page[2] stated that the temporomandibular ligament controls the amount of posterior movement of the mandible. Steinhardt[3] agreed with Arstad[4] that the capsular ligaments of the temporomandibular joint limit the posterior movements of the mandible. Various opinions are held by different investigators as to the functional importance of the anatomic structures involved in limiting retrusive movements of the mandible.[5]

The purpose of this article is to determine if the ligaments are responsible for limiting posterior movements of the mandible. The effects of severing the temporomandibular ligaments in unembalmed human cadavers and living human patients were observed.

MATERIALS AND METHODS

Gothic arch (needle point) tracings were made on a fresh human cadaver specimen both before and after severing the temporomandibular and capsular ligaments. Impressions were made of the relationship of the teeth of the mandible to those of the maxillae while the mandible was forced to the most retruded position both before and after severing the temporomandibular and capsular ligaments. Artificial stone casts were made from the impressions. The fresh, unpreserved specimen was a 62-year-old white man. The tests were performed only a few hours after death, before rigor mortis had set in.

Measurements were made of the relationship of the lower to the upper teeth on 27 living patients. The treatment for these patients required severing of the temporomandibular and capsular ligaments.

Impressions were made of the teeth of the lower jaw of each patient in relation to the teeth of the upper jaw while the mandible was forced to its most retruded position. After severance of the temporomandibular and capsular ligaments, similar impressions were made at intervals of 1 hour, 2 weeks, 3 months, and in three instances 6 months. Artificial stone casts were made in all of the impressions.

This investigation was supported by Public Health Fellowship DF-8205.
This preliminary report will be part of a thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Anatomy, Marquette University Graduate School.
*Graduate student, Department of Anatomy, Marquette University Graduate School.

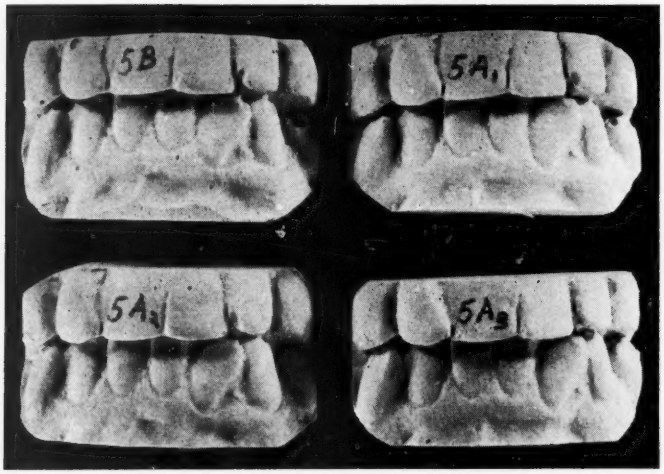


Fig. 1.—Artificial stone casts made while the mandible was forced to its most retruded position, both before and after severing the temporomandibular and capsular ligaments, show that the relation of the upper and lower teeth is identical.

All patients were women, with an average age of 42 years. All had good alveolar bone structure.

RESULTS

Needle point tracings made on the fresh human specimen before and after severing the temporomandibular and capsular ligament were identical. Measurements of the distance between the lingual incisal edge of the upper teeth and the labial incisal edge of the lower teeth before and after severing the temporomandibular and capsular ligaments and with the mandible forced to its most retruded position were identical.

Measurements of the relationship of the casts of the lower teeth to the upper teeth of the 27 living patients made before severing the temporomandibular and capsular ligaments were identical to those made after severing the ligaments. There was no lateral deviation of the mandible to the operated side on any patient (Fig. 1). This refers to the comparison of the casts made while the mandible was forced to the most retruded position.

DISCUSSION

The results obtained from the fresh human specimen indicate that neither the temporomandibular nor capsular ligaments are responsible for limiting retrusion of the mandible. These results differ from those reported by Aprile and Saizar.[1] However, our experiments cannot be considered completely valid. It is possible that the condyles may have been forced back to contact the posterior slope of the articular fossa both before and after severance of the ligaments. The use of roentgenograms would have made the results more valid.

The temporomandibular ligaments and capsular ligaments were severed unilaterally in the 27 living patients. There would be little change in the posterior direction since only one ligament was severed. However, if the ligaments were responsible for limiting retrusive movements, there should have been a slight lateral deviation of the lower midline to the operated side.

SUMMARY

It appears that neither the temporomandibular nor the capsular ligaments are responsible for limiting posterior border movements of the mandible. Further investigation of this problem is indicated.

Acknowledgment is made to Dr. Walter Zeit, Professor and Chairman of the Department of Anatomy, Marquette University Medical and Dental Schools, and to Dr. R. P. Gingrass, Professor and Chairman of the Department of Oral Surgery, Marquette University, School of Dentistry.

REFERENCES

1. Aprile, H., and Saizar, P.: Gothic Arch Tracing and Temporomandibular Anatomy, J.A.D.A. **35**:256-261, 1947.
2. Page, H. L.: Temporomandibular Joint Physiology and Jaw Synergy, D. Digest **60**:54-59, 1954.
3. Steinhardt, G.: Anatomy and Physiology of the Temporomandibular Joint: Effect of Function, Internat. D. J. **8**:155-156, 1958.
4. Arstad, T.: The Capsular Ligaments of the Temporo-Mandibular Joint and Retrusion Facets of the Dentition in Relationship to Mandibular Movements, Monograph, Oslo, 1954, A. W. Brøggers Boktrykkeri.
5. Boucher, L.: Observations on Arthrodial Types of Temporomandibular Joints, J. Pros. Den. **10**:1086-1091, 1960.

Marquette University
School of Dentistry
604 North Sixteenth St.
Milwaukee 3, Wis.

THE HEIGHT OF THE OCCLUSION RIM AND THE INTEROCCLUSAL DISTANCE

MASAKATA YASAKI, D.D.S.*
Tokyo Dental College, Tokyo, Japan

THE DIFFICUTY IN MAKING JAW RELATION RECORDS in the edentulous mouth comes from the lack of the natural teeth that establish occlusion. The main considerations in determining correct occlusion are the vertical, the anteroposterior, and the lateral jaw relations.

Many methods and devices have been created to determine physiologically the correct relation of the jaws. However, techniques which are considered theoretically or physiologically correct can be applied clinically with very little success.

Some of the techniques used in the establishment of jaw relation records are: (1) the needle-point tracer with an incisal path marker, (2) closure in the most retruded position by lifting the tongue to touch a wax ball fixed at the posterior palatal border of the baseplate, (3) closure of the jaw with a swallowing action, (4) repetition of the quick "bite" motion for loosening the masseter muscle, (5) testing of the tension of the temporal muscle, (6) pressing the jaw back with the hand, (7) closure on the posterior part of a wax rim, (8) palpation of the condyles by insertion of the fingers in the ears on both sides, and (9) use of the Bimeter.

The correct centric relation may or may not be determined by these methods, even though such devices as the path marker or the Bimeter are used. The only way to obtain the correct centric relation record is to first establish the correct vertical dimension of occlusion.

INTEROCCLUSAL DISTANCE

The interocclusal distance is the space between the maxillary and mandibular teeth when the mandible is in physiologic rest position. The distance is reported as being 2 to 8 mm., and in some instances, about 10 mm. As the difference varies from 6 to 8 mm., it is difficult to determine how much space should be allowed in clinical work.

When the patient relaxes the masseter muscle slightly without opening the lips after a closure in centric occlusion, the jaw may open a small amount. As the muscles of mastication become more relaxed, the space widens, and in the third phase of rest position, the space is still wider. Just beyond this third rest position, the patient's relaxed lips part. Therefore, the mandible can assume three rest positions from centric occlusion without opening of the lips. I call these positions the first rest position, the second rest position, and the third rest position.

*Professor of Prosthetic Dentistry.

When the lips are closed naturally, the mandible assumes the correct antero-posterior and lateral position for the construction of dentures. Only the vertical dimension must be modified.

From these facts, we assume that the mandible is flowing within the soft tissues around the mouth when opening from centric occlusion to the third rest position. This is the true action of the masticating movement. The relation of the distance between the base of the nose and the chin and the interocclusal distance in the three rest positions of the mandible is important in determining the individual physiologic rest position.

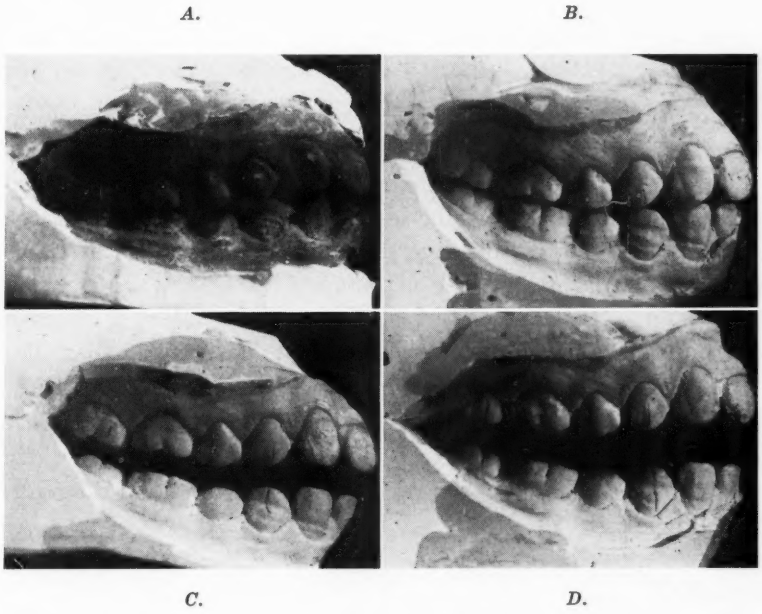


Fig. 1.—The interocclusal distance varies with the three rest positions. *A*, Centric occlusion. *B*, The first rest position. *C*, The second rest position. *D*, The third rest position.

MEASURING THE INTEROCCLUSAL DISTANCE AND NASO-CHIN DISTANCE

The interocclusal distance and the naso-chin distance were measured on 30 nurses and physicians who understood the movements of the mandible. The three rest positions were observed before making jaw relation impressions with an alginate impression material (irreversible hydrocolloid). The impression material was placed over the upper and lower teeth on one side of the mouth, the patient closed into centric occlusion, and then he relaxed to the first rest position. The impression was poured in plaster on both sides, and the casts were mounted on an articulator. Thus, four plaster casts were made including the centric occlusion of each subject (Fig. 1).

The distance from the nose to the chin was measured each time with the impression material in the mouth. A vertical line on the plaster casts at the upper first bicuspid and second molar was used to measure the distance between the two points.

In 17 out of the 30 subjects, the change in the naso-chin distance between centric occlusion and the first rest position could not be detected. The remainder of the subjects showed 0.5 to 0.2 mm. change.

At the second rest position, the naso-chin distance increased about 1 mm. in 15 subjects and 2 to 3 mm. in 15 subjects. At the third rest position, the distance increased 1.2 to 3 mm. in 17 subjects and more than 3.2 mm. in 13 subjects. Twenty subjects (70 per cent) showed no detectable change in the naso-chin distance from centric occlusion to the second rest position. A change of more than 3 mm. indicates the jaw to be in the third rest position. No change in the distance indicates the mandible is in the first or second rest position.

AMOUNT OF INTEROCCLUSAL DISTANCE

Generally, the interocclusal distance was wider at the first bicuspid than in the second molar region in the first rest position. The distance averaged 1.42 mm. at the first biscuspid and 1.12 mm. at the second molar. In the second rest position, the distance averaged 2.8 mm. at the bicuspid and 2.5 mm. at the second molar. In the third rest position, the distance averaged 6.1 mm. at the first bicuspid and 4.75 mm. at the second molar. The minimum distance was 2.7 mm. at the first bicuspid and 4.5 mm. at the second molar in the third position. The maximum distance was 8 mm. at the first bicuspid and 10 mm. at the second molar. The distance between the points of measurement (bicuspid and molar) averaged 28.8 mm.

These investigations showed that the lower jaw may follow one of five paths from centric occlusion to the third rest position. I named these paths the cross type, the type parallel in front, the Y-shaped type, the type parallel in the posterior part, and the mixed type (Fig. 2).

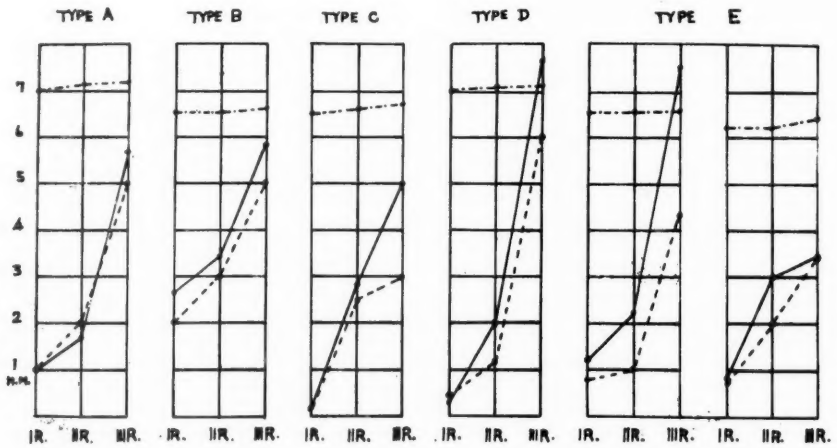


Fig. 2.—The mandible follows one of five paths from centric occlusion to the third rest position; the change in the naso-chin distance is shown: (————) amount of the free-way space at the first bicuspid; (– – – – –) amount of the free-way space at the second molar; (–.–.–.–) amount of the naso-chin distance.

THE RELATION OF THE CONDYLE AND REST POSITION OF THE MANDIBLE

We have believed that the interocclusal distance is 2 to 8 mm. and that the lower jaw drops vertically from centric occlusion. No one has explained how the mandible is positioned at rest or the correct movements of the condyle during mastication.

If a straight line is drawn from the tip of the buccal cusp of the lower second molar to the tip of the buccal cusp of the lower first bicuspid in the centric occlusion position, lines to the same points at the first, the second, and the third rest positions of the jaw form definite angles. The line at the first rest position forms an angle of 4 degrees with the centric occlusion line; 3 degrees is formed by the second rest position line and 5 degrees by the third rest position line (Fig. 3). Therefore, the condyle rotates from occlusion to the first rest position on a line axis which passes through both condyles. This action accompanies the loosening of the temporomandibular ligaments. The condyle drops vertically about 1.5 mm. and rotates up to the second rest position, moves forward about 1.5 mm. to the third

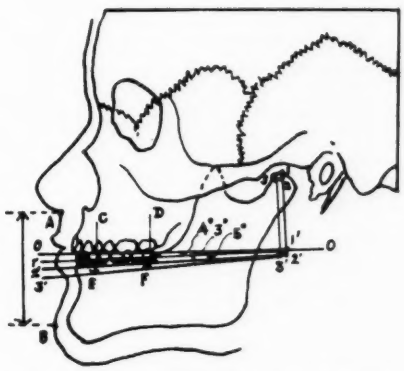


Fig. 3.—The relations of the three rest positions and the positions of the condyle: (1, 2, and 3) the positions of the condyle in the three rest positions; *(OD)* the centric occlusion line; *(1'1')* the occlusal line at the first rest position; *(2'2')* the occlusal line at the second rest position; *(3'3')* the occlusal line at the third rest position; *(A)* the point on the base of the nose; *(B)* the point overlying the mentalis muscle; *(C)* the line at the distobuccal cusp of the first bicuspid; *(D)* the line at the distobuccal cusp of the second molar; *(E)* the direction of motion of the first bicuspid from the second to the third rest position; *(F)* the direction of motion of the second molar from the second to the third rest position.

position, and rotates further. As seen in a geometric drawing (Fig. 3), the condyle may move in one of several directions within the limits of the triangle formed by the three directions of movements of the mandible in mastication.

In the third rest position, the mandible protrudes about 1 to 1.5 mm. beyond the second rest position. However, the mandible drops vertically to the second rest position from centric occlusion. Fig. 4 shows a roentgenogram which was exposed at centric occlusion and the second and third rest positions. The roentgenogram shows no change in the location of the condyle between centric occlusion and the second rest position.

CLINICAL VALUE OF THE INTEROCCLUSAL DISTANCE

The measuring method using the naso-chin distance does not interfere with free movement of the mandible. Therefore, it is the best method of determining the physiologically correct position. Generally, occlusion rims are trimmed about 2 mm. shorter than the physiologic rest width. Yet, no one seems to understand the value of this space when determining centric relation.

The mandible may assume any optimum position between centric occlusion and the third rest position. The correct position of the mandible cannot be freely determined, because no standard interocclusal distance can be detected outside the mouth. Since the vertical dimension of occlusion must closely match the height of the occlusion rims to determine centric relation, the vertical dimension must be found first; then, the interocclusal distance can be used as a point of reference.

Fig. 4.—A roentgenogram shows the condylar position for the three rest positions.

The height of the lower occlusion rim is established with the idea that food can be controlled over the occlusal surfaces with the tongue. For that reason, the lingual edge of the occlusion rim in the bicuspid region is on the same plane as the margin of the tongue while the mandible rests in the third position. The posterior end of the rim terminates at the anterior margin of the retromolar pad. The anterior plane of the occlusion rim is an extension of the plane determined in the posterior region. The occlusal plane established by this method does not coincide with Gysi's plane. Gysi's plane is adapted to indicate the inclination of the condyle path, while the plane I have described is designed for practical tooth arrangement.

The plane of the upper occlusion rim should be regulated by the lower rim, except that the lip length often influences the length of the anterior part of the occlusion rim. The amount of the upper incisors exposed under the lip varies, and the experience of the dentist determines whether advantage will be taken

of opportunities for esthetic appearance. Therefore, the occlusal plane is established by the anterior part of the upper occlusion rim and the posterior portion of the lower rim.

All surfaces of the occlusion rims must contact, and the bases supporting the rims must fit the tissue so that the vertical dimension of occlusion will be correct when the centric relation record is made. Only the naso-chin distance and interocclusal distance can be observed to verify the correct height of the occlusion rims.

TECHNIQUE FOR ESTABLISHING CENTRIC RELATION

The naso-chin distance is measured three times, at the first, second, and third rest positions without the occlusion rims in the mouth. The distance at the first and second rest positions may be almost the same. Next, the occlusion rims are placed in the mouth and the height of the rims is modified as described. Then, the naso-chin distance is measured after the lips are closed. This distance should be the same as that before the rims were placed in the mouth. This distance will show that the height of the occlusion rims includes the interocclusal distance at the first or second rest position.

After the lower occlusion rim is trimmed about 2 mm., the patient closes the lips and the naso-chin distance is measured again. If there is no change in the distance, the height of the rim correctly reflects the vertical dimension.

The patient closes in centric relation and relaxes the mandible to the first rest position. The dentist looks in the mouth by lifting the corner of the upper lip to see how much space is present between the rims. The same procedure is followed for the second and third rest positions. The height of the occlusion rims is correct for that patient if the space is 1 to 1.5 mm. at the first rest position, about 3 mm. at the second position, and more than 6 mm. at the third rest position.

It is difficult to judge the correct width of the space as 1 mm. or 1.5 mm. at the first rest position. Minimum errors should be corrected by calling on the clinical experience of the dentist.

CONCLUSIONS

1. The mandible has three rest positions according to the patient's intention. Therefore, the interocclusal distance may appear as three different distances.
2. The distance from the base of the nose to the center of the mentalis muscle does not change between centric occlusion and the first rest position.
3. The interocclusal distance does not vary with age or sex. However, some differences may appear from anatomic or physiologic individuality.
4. A mechanical device attached to the occlusion rim as an incisal path marker or a Bimeter may interfere with correct jaw relation determination.
5. The interocclusal distance has no direct value in determining the vertical dimension and is used only for reference after that dimension is determined.

Tokyo Dental College
Tokyo, Japan

AN EVALUATION OF THE FACE-BOW MOUNTING

LAWRENCE A. WEINBERG, A.B., D.D.S.
Brooklyn, N. Y.

THE MAXILLARY ARCH has a definite three dimensional relationship to all condylar motion (Fig. 1). Deviation from this relationship on the articulator produces some changes in the occlusal anatomy. This article describes the correlation between the maxillary arch and condylar motion and evaluates the effect of errors in the face-bow transfer.

Either the anatomic[1] or the kinematic hinge axis face-bow transfer is the first step in recording the relationship of the maxillary arch to the condylar paths. These two methods of maxillary cast orientation differ basically only in accuracy. Once the maxillary cast is oriented on the articulator, the centric relation record completes the static, or starting, relationship between the maxillae and the condyles in the temporomandibular fossae. From this static starting position, dynamic eccentric condylar movements are imitated by means of eccentric interocclusal records or extraoral tracings.

ESSENTIAL STEPS IN THE FACE-BOW MOUNTING

Two essential steps are necessary to orientate the maxillary cast on the articulator. First, the transverse hinge axis of the patient must be located kinematically, as in Gnathology[2] or by anatomic average measurements.[3] Second, an anterior point of orientation is selected which forms a horizontal plane of reference when a line is drawn through this point and the transverse hinge axis. Some techniques accomplish this step by orientating the occlusal plane parallel with the base of the articulator.

TRANSVERSE HINGE AXIS LOCATION

The pin point location of the transverse hinge axis is indicated only with Gnathologic procedures, since dynamic extraoral tracings are used to imitate the three dimensional movements of the hinge axis on the instrument. With other articulators, particularly the semiadjustable type (Hanau), the pin point location of the transverse hinge axis is not necessary. It has been shown mathematically[4] and experimentally[5] that reasonable errors in the transverse hinge axis location ($\pm$ 5 mm.) produce extremely small anteroposterior mandibular displacement when the centric relation record is removed and the articulator is closed (Fig. 2).

The same reasonable error in the transverse hinge axis location ($\pm$ 5 mm.) has practically no effect on eccentric interocclusal record readings on the articulator (see Figs. 12 to 17). This evidence supports the view that the transverse hinge

axis can be located by anatomic average measurements on a line from the middle of the tragus of the ear to the corner of the eye. The pins of the face-bow are adjusted 11 to 13 mm. from the posterior border of the tragus on the tragus-eye line.

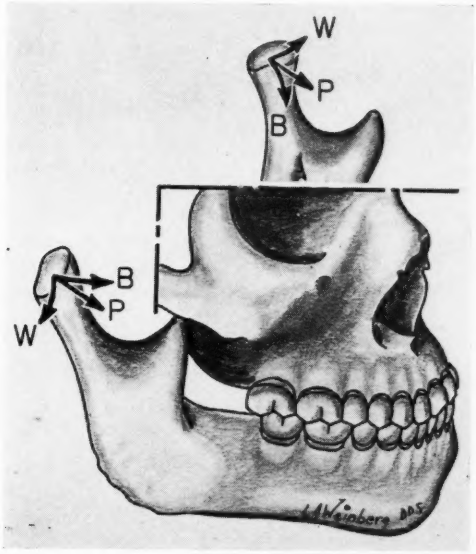
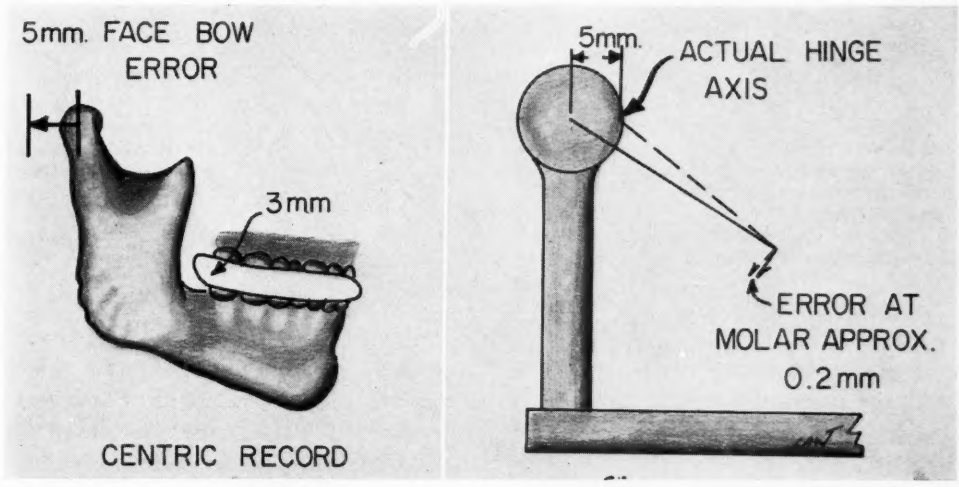


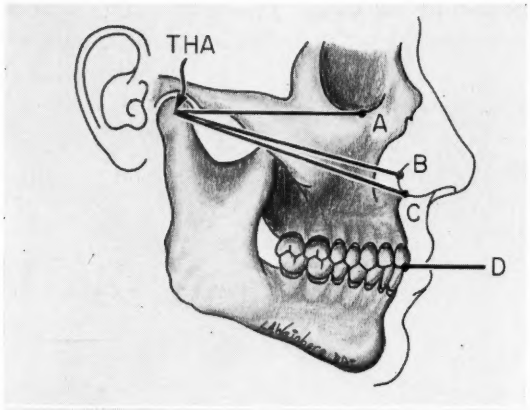
Fig. 1.—The maxillary arch has a definite three dimensional relationship to all condylar motion: *(P)* the "pure" protrusive; *(W)* the working; *(B)* the balancing movements, usually used for recording purposes and sometimes referred to as the border movements.



A. *B.*

Fig. 2.—*A*, The pins of the face-bow were erroneously placed 5 mm. distal to the actual transverse hinge axis of the patient. The lower cast is mounted with a centric relation record of 3 mm. thickness at the second molar. *B*, When this centric relation record is removed, the articulator closes on its hinge axis rather than the hinge axis of the patient. The anteroposterior displacement at the second molar is approximately 0.2 mm.

Fig. 3



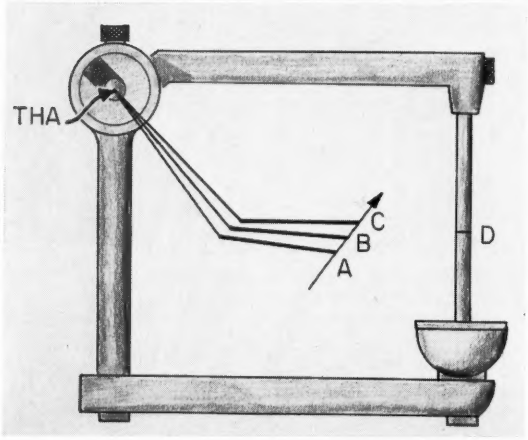


Fig. 4

Fig. 3.—Different techniques used in the selection of the anterior point of orientation are: *(A)* an orbital pointer which is placed near the top of the articulator for maxillary cast mounting; *(B)* the orientation of the occlusal plane parallel with the tragus-ala line or the tragus–anterior nasal spine line; *(C)* the incisor teeth or occlusion rim made level with the notch on the incisal pin *(D)* (Hanau).

Fig. 4.—The various anterior points of orientation seen in Fig. 3 raise or lower the face-bow. As the face-bow is raised, it moves slightly forward.

ANTERIOR POINT OF ORIENTATION

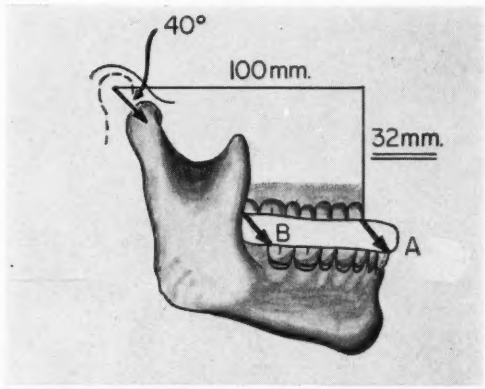
Variation exists in the selection of the anterior point of orientation which with the transverse hinge axis forms the horizontal plane of reference. Some techniques call for the use of an orbital pointer which is placed near the top of the articulator for maxillary cast mounting. Others place the plane of occlusion parallel to the ala-tragus line, while still others use a line from the tragus of the ear to the anterior nasal spine. Some techniques call for the plane of occlusion and/or the ridges to be roughly parallel to the base of the articulator. The incisal edge of the teeth or occlusion rim can be made level with the notch on the incisal guide pin of the Hanau model H articulator (Fig. 3.).[6] These various anterior points of orientation raise or lower the anterior part of the face-bow less than ± 16 mm. (Fig. 4).

EFFECT OF RAISING OR LOWERING THE PLANE OF OCCLUSION

Raising or lowering the face-bow mounting has no effect on centric occlusion. However, it does have an effect on eccentric condylar readings which influence cusp inclines. For example, as the plane of occlusion is elevated, the condylar readings decrease. Conversely, as the occlusal plane is lowered, the condylar readings increase.

These changes are fairly simple to visualize, but to evaluate their effect, they must be related to the degree of change that is produced at the cusp inclines. This relationship can be illustrated by comparing the cuspal structure of an average patient with cusp inclines produced on the articulator because of errors in the face-bow mounting. To illustrate, when the face-bow is oriented 16 mm. too high, the identical protrusive record produces a reduction in the condylar path on the articulator from 40 degrees (Fig. 5) to 31 degrees (Fig. 6).

Fig. 5



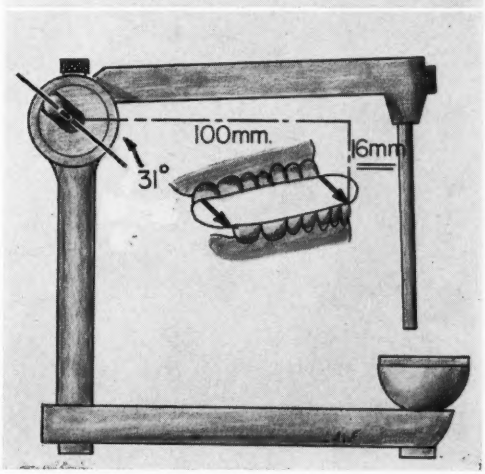


Fig. 6

Fig. 5.—A patient has bilateral condylar paths of 40 degrees: *(A-B)* an interocclusal protrusive record is in position. Average indicated dimensions are used.

Fig. 6.—The face-bow is oriented 16 mm. too high. The identical protrusive record produces a reduction in the condylar path on the articulator from 40 degrees to approximately 31 degrees. Most accepted techniques would not vary the height of the occlusal plane more than ± 16 mm.

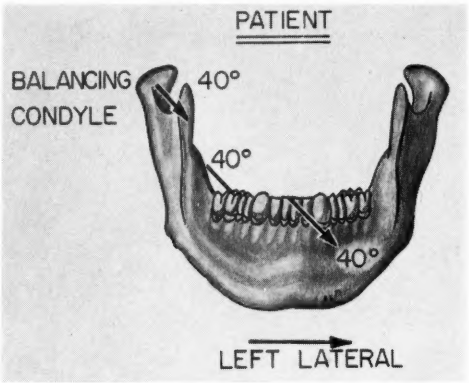
RELATIONSHIP OF CONDYLAR PATHS AND INCISAL GUIDANCE TO CUSPAL INCLINES

The three dimensional relationship of the condylar paths, incisal guidance, and cuspal inclines has been described.[7-9] Briefly, the balancing condyle path, the balancing cusp inclines, and the incisal guidance can be considered to be approximately in a straight line. The individual balancing cusp inclines vary in their inclination depending on their location between the extreme guiding factors of the balancing condyle and the incisal guidance (Fig. 7).

The working cusp inclines are similarly related to their location between the extreme guidances on the working side. These guidances are the working condyle path (zero degrees on the Hanau articulator) and the incisal guidance.

Effect of Condylar Changes on Balancing Cusp Inclines.—If the face-bow mounting is oriented 16 mm. too high on the articulator, the condylar readings

Fig. 7



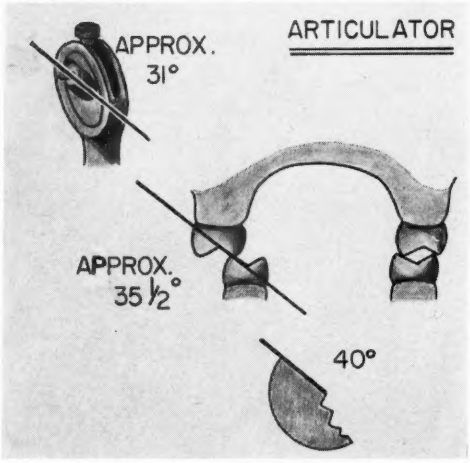


Fig. 8

Fig. 7.—A patient with a balancing condyle inclination of 40 degrees and an incisal guidance of 40 degrees has all balancing cusp inclines of 40 degrees.

Fig. 8.—The face-bow mounting is oriented 16 mm. too high on the articulator as measured at the incisors. The condylar readings decrease from 40 degrees to approximately 31 degrees. This decrease in the balancing condyle inclination reduces the balancing cusp inclines. With the same incisal guidance of 40 degrees on the articulator, the balancing cusp inclines at the midpoint are 35.5 degrees. This is the average between the extreme guidances.

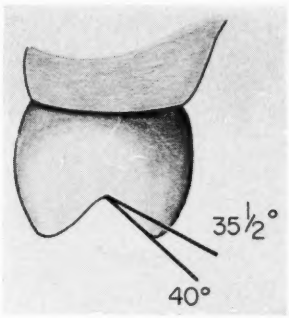


Fig. 9*A*

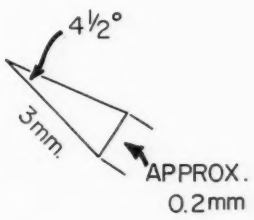


Fig. 9*B*

Fig. 9*A*.—The balancing cusp inclines of the second molar should be 40 degrees, whereas the articulator produces 35.5 degrees.

Fig. 9*B*.—With a 3 mm. cuspal incline, a decrease of 4.5 degrees produces a decrease at the cusp height of approximately 0.2 mm.

decrease from 40 degrees to approximately 31 degrees. With the same incisal guidance of 40 degrees on the articulator, the balancing cusp inclines at the midpoint are 35.5 degrees (Fig. 8). This is the average between the extreme guidances. The balancing cusp inclines of the second molar should be 40 degrees, whereas the articulator produces 35.5 degrees (Fig. 9*A*). With a 3 mm. cuspal incline, this produces a decrease at the cusp height of approximately 0.2 mm. (Fig. 9*B*).

Effect of Condylar Changes on Working Cusp Inclines.—A semiadjustable articulator such as the Hanau model H has a constant working condyle motion that is a combination of rotation and lateral Bennett movement at zero degrees

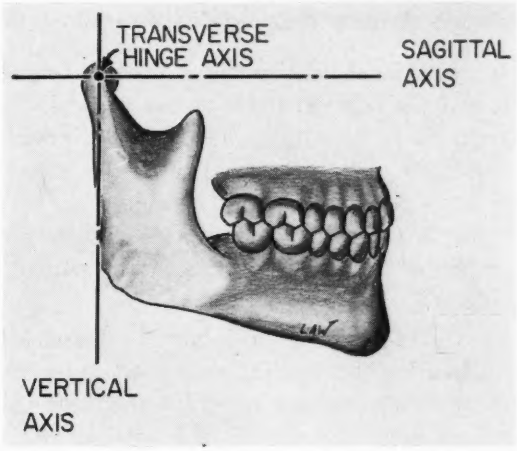


Fig. 10.—The axes of rotation of the mandible and the occlusal plane have a definite three dimensional relationship.

inclination. Therefore, a change in condylar inclination on the instrument produces no measurable effect on the working condyle motion or the working cusp inclines.

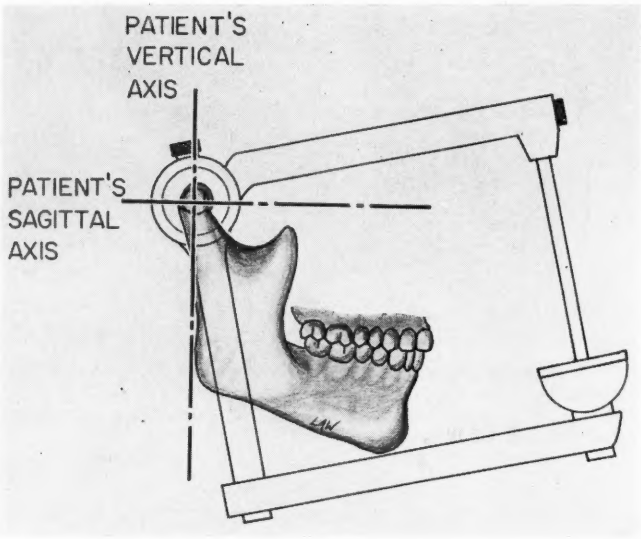


Fig. 11.—The occlusal plane is oriented too low. The vertical and sagittal axes of the patient do not correspond to these respective axes of the articulator.

Effect on the Protrusive Cusp Inclines.—Raising or lowering the face-bow mounting does not appreciably affect the protrusive (mesiodistal) cusp inclines. For example, when the face-bow is raised, the condylar readings decrease. This decrease is compensated by the simultaneous increase in angulation between the occlusal plane of the teeth and the horizontal plane of the articulator (Fig. 4).

THE PATIENT COMPARED TO THE ARTICULATOR

A definite three dimensional relationship is present between the axes of rotation of the mandible and the occlusal plane at the vertical dimension of occlusion when the jaw is in centric relation (Fig. 10). A description of the various axes of rotation of the mandible and their function during eccentric movements was presented in a previous article.[10] The horizontal plane of the articulator actually represents the sagittal axes of the patient at the vertical dimension of occlusion with the jaw in centric relation. The vertical axes of the patient are represented by the posts of the articulator.

Even though the transverse hinge axis may be found kinematically, there is no clinical method of locating the vertical or sagittal axes. The orientation of the occlusal plane is not arbitrary, because once the maxillary cast is attached to the articulator, the relationship of the cast to the vertical and sagittal axes of the instrument is established. The relationship of the maxillary cast to these axes on the articulator is different than the relationship of the maxillae to these same axes on the patient (Fig. 11). As a result of this discrepancy, protrusive records transfer erroneous condylar readings. With the semiadjustable articulator (Hanau model H), the balancing cusp inclines primarily are affected.

The magnitude of this error is so small that it justifies the use of the face-bow. However, we must be aware that it exists. This definite relationship between the maxillary cast orientation and the cuspal inclines contraindicates an arbitrary mounting.

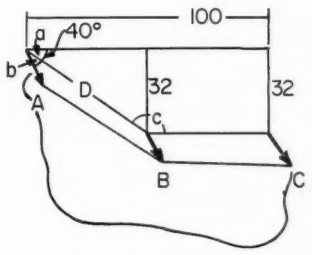
TRANSVERSE HINGE AXIS AND INTEROCCLUSAL RECORD TECHNIQUE (HANAU)

Unless a kinematic hinge axis determination is used for the face-bow mounting, approximately a ± 5 mm. error in its location must be assumed. With either method, the occlusal plane orientation is an approximation. These combined errors must be related back to the cuspal inclines in order to evaluate their effect. To illustrate, calculations show that a 5 mm. posterior error in the hinge axis location alters the second molar balancing cusp height in the magnitude of 0.03 mm.

Therefore, it can be concluded that with a semiadjustable articulator, the location of the transverse hinge axis within ± 5 mm. has no practical measurable effect on the condylar readings or the balancing cusp inclines.

The mathematical calculations and formulas for the described changes are shown in Figs. 12 through 17.

Fig. 12



$$\tan a = \frac{32}{50}$$

$$a = 32° 37' 9''$$

$$b = 40° - a$$

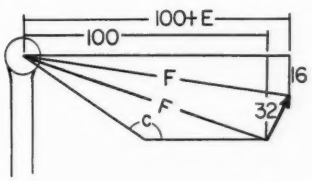
$$b = 7° 22' 51''$$

$$\sin a = \frac{32}{D}$$

$$D = 59.364 \text{ mm.}$$

$$c = 90° + (90° - a)$$

$$c = 147° 22' 51''$$



$$(F)^2 = (32)^2 + (100)^2$$

$$F = 105 \text{ mm.}$$

$$(100+E)^2 + (16)^2 = (105)^2$$

$$E = 3.78 \text{ mm.}$$

Fig. 13

Fig. 12.—The geometric status of the patient with the protrusive position. A condylar path of 40 degrees places the condyle at *A*, the second molar at *B*, and the incisors at *C*. Angles *a*, *b*, and *c* are calculated. Angles *b* and *c* and distance *D* are constant when the casts are transferred to the articulator. These angles and distances are constant because of the hinge axis location and the protrusive wax record, which are identical in the mouth or on the articulator. Angle *a* varies depending on the level of the face-bow mounting.

Fig. 13.—When the face-bow is elevated 16 mm., the maxillary cast moves anteriorly 3.78 mm.

Fig. 14

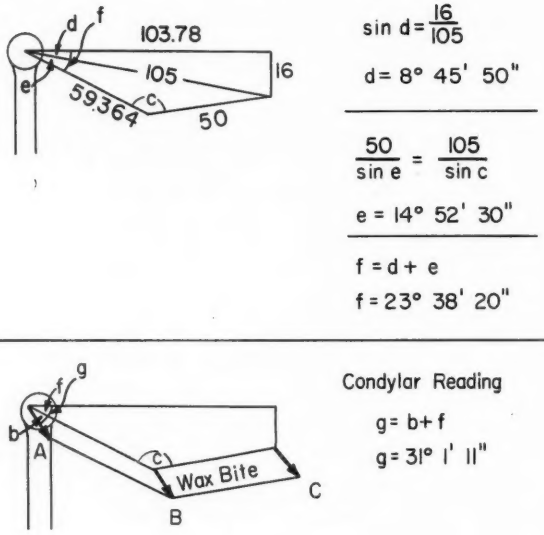


Fig. 15

Fig. 14.—Geometric solution for angle *f*, the new angle formed by the horizontal plane and the hinge axis–second molar line when the face-bow is raised 16 mm. This angle diminished from the original value (Fig. 12). The reduction of this angle causes the decrease in the condylar reading.

Fig. 15.—The decrease in condylar reading *g* is calculated by adding the constant angle *b* and angle *f*.

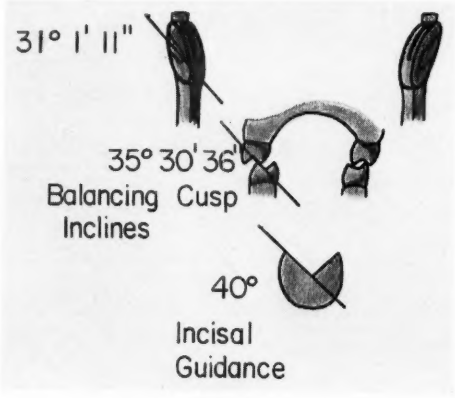


Fig. 16.—The condylar reading decreases from the original 40 degrees to 31 degrees, 1 minute, 11 seconds, when the face-bow mounting is raised 16 mm. With a constant incisal guidance of 40 degrees, the midpoint at the second molar balancing cusp incline is the average between the extreme guidances, namely, 35 degrees, 30 minutes, 36 seconds.

CONCLUSIONS

The location of the transverse hinge axis is mainly related to the accurate transfer of the centric relation record rather than eccentric condylar inclinations. A reasonable error in the transverse hinge axis location (within ± 5 mm.) results

in negligible anteroposterior mandibular displacement (in the magnitude of 0.2 mm.) when a 3 mm. centric relation record is removed and the articulator is closed. This anteroposterior displacement can be limited further by a thinner interocclusal centric relation record.

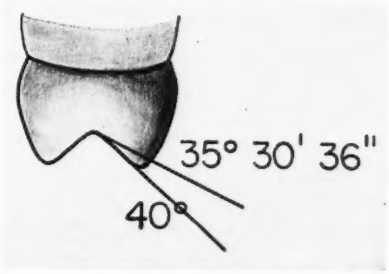
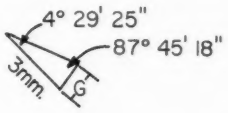


Fig. 17*A*.—The balancing inclines of the patient will be 40 degrees as seen in Fig. 7. The articulator produces a second molar balancing cusp inclination of 35 degrees, 30 minutes, 36 seconds.

When the centric relation record is obtained without a change in vertical dimension, there is no anteroposterior mandibular displacement at all. The face-bow mounting in this instance is mainly concerned with the accurate transfer of the condylar inclination. A marked change in vertical dimension because of a thick centric relation record causes gross anteroposterior mandibular displacement that requires more extensive intraoral adjustment.

Marked deviations from the transverse hinge axis of the patient, resulting from arbitrary mounting, can cause serious anteroposterior mandibular displacement



$$\frac{G}{\sin 4^\circ 29' 25''} = \frac{3}{\sin 87^\circ 45' 18''}$$

$$G = 0.23497 \text{mm.}$$

Fig. 17*B*.—With a 3 mm. cuspal incline, the error at the cusp height is 0.23497 mm.

even with small vertical dimension changes. Eccentric records with an arbitrary mounting are practically valueless.

The orientation of the occlusal plane is primarily related to the accurate transfer of the eccentric condylar inclinations rather than the centric relation record. Elevation of the occlusal plane decreases the condylar readings; lowering the occlusal plane increases them. With any of the commonly used anterior points of orientation, the degree of variation produced is in the magnitude of 0.2 mm. at the second molar balancing cusp and less anteriorly.

The working cusp inclines are not measurably affected by changes in the condylar readings. In normal use, the working condyle movement on the Hanau type articulator is constant regardless of the condylar readings. It consists of rotation with a lateral Bennett movement of zero degrees.

The small degree of error at the balancing cusp inclines is well within the accuracy of the cast construction, centric relation record, and the instrument itself. However, completely arbitrary maxillary cast mounting can produce not only significant anteroposterior mandibular displacement but also serious cuspal inclination disharmonies.

SUMMARY

Reasonable working errors in the application of the nonkinematic face-bow transfer were evaluated by relating these errors to the effect produced at the cuspal inclines. This evaluation led to the conclusion that the nonkinematic face-bow mounting is an essential step in the construction of restorations that will require the least intraoral correction.

REFERENCES

1. Snow, G. B.: Articulation, D. Cosmos. **42**:531-535, 1900.
2. McCollum, B. B.: Fundamentals Involved in Prescribing Restorative Dental Remedies, D. Items Interest **61**:522-535, 641-648, 724-736, 852-863, 942-950, 1939.
3. Swenson, M. G.: Complete Dentures, ed. 3, St. Louis, 1953, The C. V. Mosby Company, p. 301.
4. Weinberg, L. A.: The Transverse Hinge Axis: Real or Imaginary, J. Pros. Den. **9**:775-787, 1959.
5. Kurth, L. E., and Feinstein, I. K.: The Hinge Axis of the Mandible, J. Pros. Den. **1**:327-332, 1951.
6. Hanau, R. L.: Full Denture Prosthesis, ed. 4, Buffalo, 1930, Hanau Engineering Co., p. 30.
7. Schuyler, C. H.: Factors of Occlusion Applicable to Restorative Dentistry, J. Pros. Den. **3**:772-782, 1953.
8. Weinberg, L. A.: The Occlusal Plane and Cuspal Inclination in Relation to Incisal-Condylar Guidance for Protrusive Excursions, J. Pros. Den. **9**:607-618, 1959.
9. Weinberg, L. A.: Incisal and Condylar Guidance in Relation to Cuspal Inclination in Lateral Excursions, J. Pros. Den. **9**:851-862, 1959.
10. Weinberg, L. A.: Physiologic Objective of Reconstruction Techniques, J. Pros. Den. **10**:711-723, 1960.

515 Ocean Ave.
Brooklyn 26, N. Y.

REGISTRATION OF THE CONDYLE PATH INCLINATION BY INTRAORAL WAX RECORDS—ITS PRACTICAL VALUE

ULF POSSELT, L.D.S., ODONT. DR.,* AND PER NEVSTEDT, L.D.S.
The Royal Dental School, Malmö, Sweden

THE VALUE OF THE CONDYLE PATH INCLINATION as obtained from interocclusal wax records and the adjustment of the condyle path of the articulator depend on a number of factors during both the registration and the reading. The error of the single observation for the Dentatus articulator has been calculated to 2.3 degrees.[1] This value constitutes the average error of protrusions of 4 to 8 mm. in 10 persons with natural teeth (Table I). The figure is valid for a trained "operator."† The variation between different operators was not examined in the previous investigation.[1]

As mentioned previously, the articulator has an error of measurements of about 2.3 degrees.[1] This number (2.3) multiplied by the square root of 2 and multiplied by 2.5 results in an amount of 8.1 degrees. This number of degrees decides the difference between two single determinations of condyle path inclination which must be present for the two records to be differentiated.

As the selectivity of the method is known, the next question is how often does the condyle path inclination deviate more than 8.1 degrees from a suitable mean value.

This investigation was designed to determine the frequency of condyle path inclinations, with the error of measurement found with the Dentatus articulator as a background.

MATERIALS

One hundred and one subjects (60 women, 41 men) were selected at random from the Department of Occlusal Analysis of the Royal Dental School, Malmö, Sweden. The average age was 35 years and the average number of teeth present was 26.

The distribution of the frequency of the condyle path inclinations is seen in Fig. 1. The average shift of the condylar spheres for 30 subjects was 4.4 mm. (standard deviation 1.7 mm.). The condyle path inclinations were measured in relation to the "Frankfort plane."

The average inclination was 39.1 degrees on the right side and 40.4 degrees on the left side, with a range of 60 degrees. The Dentatus articulator cannot be

*Head of the Department of Occlusal Analysis and Rehabilitation.

†The "operator" is the one who undertakes the intraoral registration of wax records. The "reader examiner" places the wax records on the casts, adjusts the condyle paths, and reads the condyle inclination.

adjusted to a condyle path inclination steeper than 60 degrees. The distribution of frequency (Fig. 1) is asymmetric, which may be due to this upper limit in adjustment of the Dentatus articulator.

RESULTS

Results indicated that individual registrations of the condyle paths should be used, instead of the mean value adjustment of 40 degrees, when a patient had a condyle path inclination amounting to more than 49 degrees or not exceeding 31 degrees. This will be true in 50 per cent of the patients.

If one is not satisfied with this selectivity, the reliability can be increased by repeating the determination of the condyle path inclination. Four independent repetitions cause the difference from the mean value adjustment, as demanded for a statistically established difference, to be diminished by one-half.

TABLE I. MEANS AND STANDARD DEVIATION OF CONDYLE PATH INCLINATIONS

DEGREE OF PROTRUSION (MM.)	DENTATUS ARTICULATOR		
	M	SD*	
		Os	Ks
4	30.1	2.5	20.8
6	30.9	2.0	17.2
8	30.0	2.3	15.6
Average	30.3	2.3	17.9

The condyle path inclination was measured in relation to the occlusal plane.

*The standard deviation was divided into the variance inside the classes and the variance between classes. This involved the error of the single observation *(Os)* and further the sensitivity partly for examiner (difficulty in reading the instrument) and partly for different condyle path inclinations *(Ks)*.

DISCUSSION

A comparison between the graphic registration according to the Gysi method and the interocclusal wax record registration seems to favor the latter.[2] Provided a comparison between results from complete dentures and natural dentitions is allowed and provided also the results are caused by the record technique, the findings seem to coincide with those of Ekensten.[3]

The technique of the various operators seems to have great significance.[4] The 202 condyle path inclinations were measured by students under the supervision of instructors. Therefore, it is conceivable that one or a few trained dentists would have obtained fewer deviations. For example, it is striking that 22 per cent of the values are below 30 degrees. On the other hand, one should consider that the 101 cases certainly included pathologic conditions of the temporomandibular joints, for instance, distal displacement of condyles.

An attempt toward individual condyle path registration naturally implies that the imitation of relatively large gliding movements on the articulator is considered of value. Not all articulation theories have this as a goal.

Whether or not an adjustment of the condyle path inclination is meaningless because of the shortness of the path during functional contact movements is another question. The opinion depends on a number of factors, especially which movement one wishes to imitate on the articulator. Therefore, the question can hardly be answered in general.

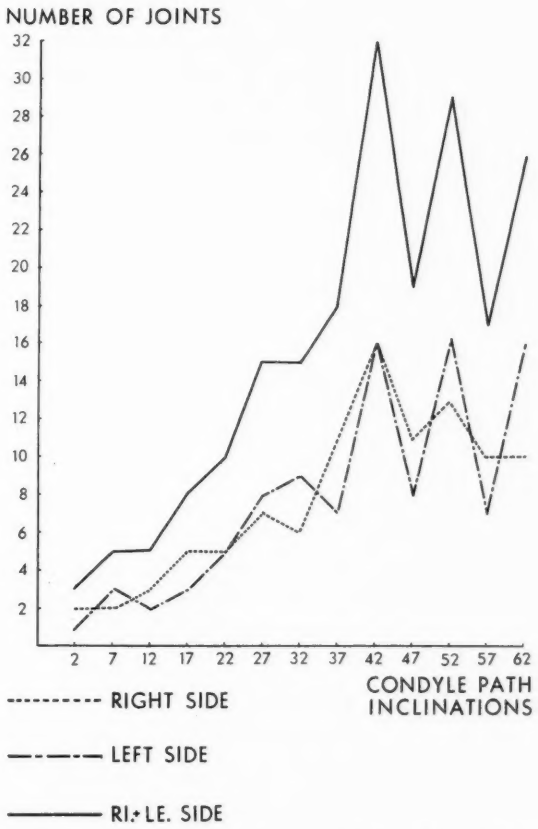


Fig. 1.—The distribution of the frequency of the condyle path inclinations.

The first and foremost advantage of the articulator is its capability to secure definite relations between the mandible and the maxillae. The instrument is further able to imitate paths of movements between these positions approximately correctly.

The use of the movement path after adjustment of the individually adjustable articulator depends to a large degree on clinical training and common sense. The positional registration is the primary thing. The starting position, centric relation, again is the most important of all.

Several authors[5-8] deal with the question of how much a change in the condyle path inclination changes tooth to tooth relations during movements on the articu-

lator. Craddock[5] states that a change of the condyle path inclination of 10 degrees results in a vertical change at the molars of 0.5 mm. Marolt[7] points out that with a change of 15 degrees of the condyle path inclination, the vertical relation of the second molar changes only 0.5 mm. during protrusion. He evidently places the limit of tolerance here. Nevakari[8] states that in 96 per cent the vertical error in the molar region on protrusion, after the adjustment of an average condyle path inclination of 45 degrees, will be 0.5 mm. or less. Hanau[6] puts a much more narrow margin (0.1 mm.) for what is tolerable in the vertical direction. Unfortunately, Hanau[6] does not show how he has arrived at this limit of tolerance, neither do other authors explain why they consider values in the vicinity of or immediately below 0.5 mm. to be without significance.

Therefore, the values, which have been stated as insignificant do not appear completely convincing. It is likely that such vertical differences play a lesser role in complete dentures than in natural dentitions. Clinical experience indicates that even minimum occlusal disturbances in natural dentitions can be of significance.

CONCLUSION

This investigation indicates that the condyle path registration, as determined with interocclusal wax records, can have some value. However, the present study only gives some aspects on the problem. The variation between different "reader examiners" should be further investigated, and the limit of tolerance for changes in the occlusal relationship of the teeth should also be examined.

SUMMARY

The frequency of condyle path inclinations with the error of measurement for the Dentatus articulator as a background was investigated. The error of measurement for one operator has previously been reported.

The condyle path inclinations in 101 subjects, as determined by interocclusal wax records, varies between 0 and 60 degrees. The greatest frequency is around 40 to 50 degrees as related to the Frankfort plane.

The minimum established difference between two single condyle path inclinations was calculated to be between 8 and 9 degrees.

Disregarding the variation between different operators (which should be further investigated), the condyle path registration by means of interocclusal wax records possesses some value.

REFERENCES

1. Posselt, U., and Franzén, G.: Registration of the Condyle Path Inclination by Intraoral Wax Records: Variations in Three Instruments, J. Pros. Den. **10**:441-454, 1960.
2. Posselt, U., and Skytting, B.: Registration of the Condyle Path Inclination: Variations Using the Gysi Technique, J. Pros. Den. **10**:243-247, 1960.
3. Ekensten, B.: Jämförande undersökningar över graden av artikulationsjämvikt vid proteser utförda i medelvärdeszoch individuella artikulatorer, Odont. tskr. **55**:1-48, 1947.
4. Nevakari, K.: Sagittaalisen leukanivelradan yksilöllisen kaltevuuden määrittämistarkkuudesta intraoraalista vahaindeksitekniikkaa käyttäen (Observations Concerning the Accuracy in Registering the Sagittal Condylar Guidance with the Intraoral "Check-bite" Method), Finska tandläk. sällsk förhandl. **53**:205-212, 1957.

5. Craddock, F. W.: The Accuracy and Practical Value of Records of Condyle Path Inclination, J.A.D.A. **38**:697-710, 1949.
6. Hanau, R. L.: Dental Engineering. Shall We Adjust an Articulator to Anatomical and Technical Requirements or May We Expect Our Patients to Fit an Average Articulator? J.N.D.A. **9**:595-609, 1922.
7. Marolt, A.: Der praktische Wert der Messung der sagittalen Kondylenbahn für die Prothetik, Schweiz. Monaschr. Zahnhk. **64**:948-959, 1954.
8. Nevakari, K.: Alaleuan toiminnallinen protruusioliike (The Functional Protruding Movement of the Mandible), Finska tandläk. sällsk. förhandl. **54**:94-120, 1958.

THE ROYAL DENTAL SCHOOL
MALMÖ, SWEDEN

THE EFFECT OF INCISAL GUIDANCE ON CUSP ANGULATION IN PROSTHETIC OCCLUSION

FINN TENGS CHRISTENSEN, L.D.S.*
Stavanger, Norway

THE OBJECT of this article is to clarify the relationship between the sagittal cusp angulation and the inclination of the incisal guidance. Swenson[1] has expressed the relation by means of the following formula:

$$\text{Cusp inclination} = \text{Incisal inclination} + \text{Fraction of distance from incisal guidance} \left(\text{Condyle inclination angle} - \text{Incisal inclination angle} \right)$$

If the cusp angulation is Σ, the inclination of incisal guidance is v, the condylar guide inclination is β, and the fraction of the distance from the incisal guidance is d, Swenson's formula may be expressed: $\Sigma = v + d(\beta - v)$.

Therefore, if the cusp angulation is to be in accordance with the incisal guidance and the condylar guidance, the cusp angulation varies as follows:

1. If the incisal inclination is *less* than the inclination of condylar guidance, the cusp angulation must equal the incisal inclination plus an angle that depends on the difference $\beta - v$ and the fraction of the distance from the incisal point to the cusp in question.

2. If the inclination of the incisal guidance is *equal* to the condylar guidance, that is, $v = \beta$, the cusp angulation is equal to both the inclination of incisal guidance and the inclination of the condylar guidance, that is, $\Sigma = v = \beta$ (Fig. 1).

3. If the incisal guide inclination is *greater* than the condylar guide inclination, the difference $\beta - v$ will be negative. The cusp angulation is equal to the incisal guide inclination minus an angle that depends on the difference $\beta - v$ and the fraction of the distance of the cusp in question from the incisal point.

THE DISTANCE FROM THE INCISAL POINT

Swenson's formula is an empirical formula and logically unassailable. However, it is not an exact formula. The factor d, the fraction of distance from the incisal point to the cusp in question, is the weak link. The problem is to calculate d. To solve that problem, it is necessary to determine the cusp angulation for complete dentures and the suppositions regarding the calculations of the cusp angulation when the incisal guidance is zero degrees.[2]

The calculation of the cusp angulation for complete dentures is based on the calculation of the Christensen angle (γ). The protrusive movement of the condylar

*Assistant Professor, Norwegian State Dental School, Oslo.

axis is divided into two separate movements.[2] The first movement is a parallel shift of the incisal point and the condylar axis along the incisal guidance which is assumed to be zero degrees.

The same principle is used to clarify the influence of the incisal guidance on the cusp angulation. In the present situation, the first movement is a parallel shift of, respectively, the condylar axis and the incisal point along the incisal guidance. According to Fig. 2, the condylar axis (L) is thought to move along an imaginary condylar path (LL_1) which is situated parallel to the incisal guidance (AA_1). The mandibular occlusal plane (AK) is shifted parallelly to a new position (A_1K_1). The next step is a rotation of the mandible around the incisal point (A_1) in the new position, until the condylar axis L_1 touches the real condylar path. L_1 shifts to L_2

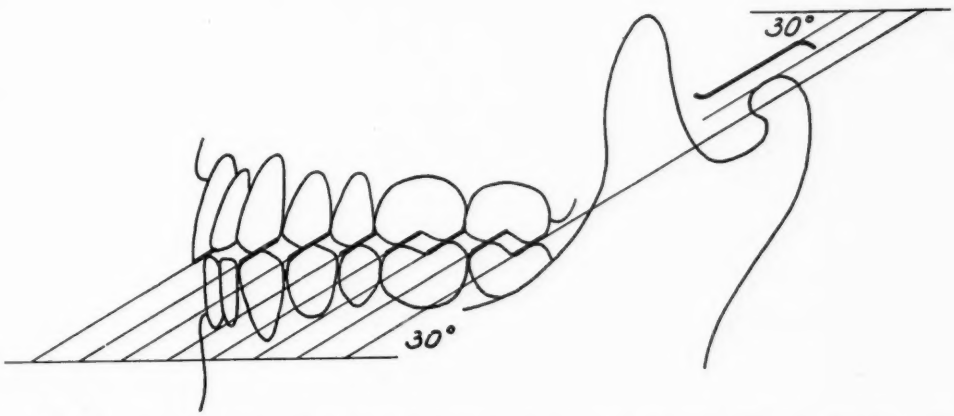


Fig. 1.—The inclination of the incisal guidance is equal to the inclination of the condylar guidance. The incisal point and the projection of the condylar axis move on parallel paths. To maintain antagonistic tooth contact along the entire length of the protrusive facets, the sagittal cusp angulation of all of the cusps must be the same size as the inclination of the incisal and the condylar guidances.

if the condylar guide inclination is greater than the incisal guide inclination. If the relation is inversed, that is, the incisal guide inclinaton is steeper than the condylar guide inclination, L_1 shifts to L_3.

The angle $K_1A_1K_2$ is formed if the condylar path inclination is steeper than the incisal guide inclination. If the relation is inversed, the angle $K_1A_1K_3$ is formed. These angles correspond to the Christensen angle, and the size depends upon the difference between the condylar guide inclination and the incisal guide inclination.

If the condylar guide inclination is the same size as the incisal guide inclination, the cusp angulation must be of the same size ($\beta = \upsilon = \Sigma$) because the incisal point and the condylar axis move on parallel paths (Fig. 1). That is in accordance with Swenson's formula. However, when there is any difference between the incisal and the condylar guide inclinations, the cusp angulation must be altered to attain complete antagonistic contact along the entire length of the protrusive facets during protrusive movements.

The difference between the incisal and condylar angles ($\beta - v$) is called the *cid* angle (condylar-incisal difference angle). If the inclination of condylar guidance is greater than the inclination of incisal guidance, the cusp angulation is equal to

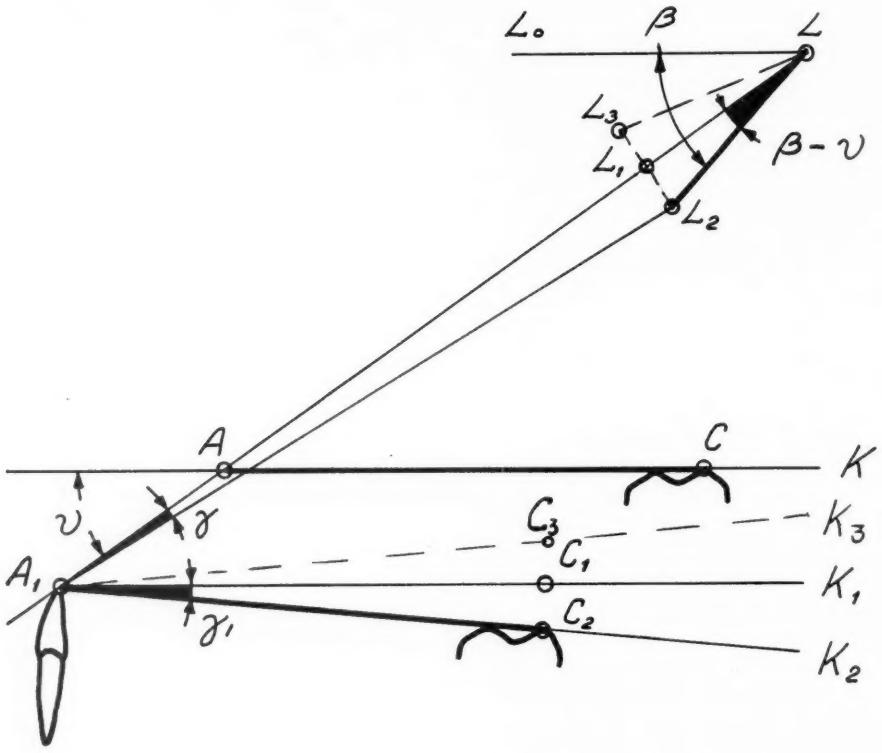


Fig. 2.—The inclination of the incisal guidance is different from the inclination of the condylar guidance: *(A)* the incisal point in centric occlusion; *(A_1)* the position of the incisal point after a protrusive movement along the incisal path; *(AA_1)* the length of the protrusion; *(AK)* the plane of occlusion; *(A_1K_1)* an auxiliary line indicating the mandibular occlusal plane after parallel shifting of the condylar axis and the incisal point along the incisal guidance; *(A_1K_2)* the mandibular occlusal plane after a protrusive gliding movement of the incisal point along the incisal path and of the condylar axis along the condylar path.

(L_0) Auxiliary letter; *(L)* the position of the condylar axis in centric occlusion; *(L_1)* the position of the condylar axis after a protrusive movement along an imaginary path *(LL_1)* parallel to the incisal guidance *(AA_1)*; *(L_2)* the condylar axis after a protrusive movement on the condylar path *(LL_2)*; *(L_3)* the position of the condylar axis after a protrusive movement if the inclination of condylar guidance is less than the inclination of the incisal guidance.

(C) The molar point in the centric occlusion; *(C_1)* the molar point after a parallel shifting of the incisal point and the condylar axis on, respectively, the incisal path and an imaginary condylar path *(LL_1)* parallel to this; *(C_2)* the position of the molar point after a protrusive movement with the incisal point along the incisal path *(AA_1)* and the condylar axis along the condylar path *(LL_2)*.

The angles γ and γ_1 correspond to the Christensen angle for a condylar guide inclination equal to L_1LL_2. L_1LL_2 is equal to the *cid* angle, which is the difference between the condylar guide inclination and the incisal guide inclination ($\beta - v$). Consequently, the cusp angulation equals the incisal guide inclination (see Fig. 1) with a correction depending on the *cid* angle. Each angle of condylar guidance, as well as each *cid* angle, has a corresponding Christensen angle. The calculation of the correction is based on the Christensen angle and can be carried out in Table I. The result is shown in Table II.

(C_3) The position of the molar point after a protrusive movement, when the inclination of the incisal guidance is steeper than the inclination of the condylar guidance.

v *plus* an angle that depends upon the *cid* angle ($\beta - v$). If the relation is inversed (β is less than v), the cusp angulation is equal to v *minus* an angle depending on the *cid* angle.

The influence of the *cid* angle on the cusp angulation when v equals zero degrees is expressed in Table I, where the *cid* angle is equal to the inclination of condylar guidance because $\beta - v = \beta - 0° = \beta$. Table II is in principle the same as the Cusp Incline Table, but the inclination of the condylar guidance has been replaced by the *cid* angle.

TABLE I. CUSP INCLINE TABLE

CUSP ANGLE (Σ)	CONDYLAR GUIDE ANGLE (β)					
	10°	20°	30°	40°	50°	60°
ΣM_3	5°	10°	15°	20°	25°	30°
ΣM_2	4°	8°	12°	16°	20°	24°
ΣM_1	3°	6°	9°	12°	15°	18°
ΣP_1P_2	2°	4°	6°	8°	10°	12°

This table indicates the relation between the sagittal cusp angle (or the tilting of cuspless posterior teeth) (Σ) and the inclination of condylar guidance (β).
M = molar; P = premolar.

Table I is based on the following ratio between the cusp angulation and the inclination of condylar guidance[2]:

$$\begin{aligned} \Sigma M_3 &= 5/10\beta \\ \Sigma M_2 &= 4/10\beta \\ \Sigma M_1 &= 3/10\beta \\ \Sigma P_1P_2 &= 2/10\beta \end{aligned}$$

Expressed by Swenson's formula, $\Sigma = v + d(\beta - v)$, the relation (with $v = 0°$) is:

$$\begin{aligned} \Sigma M_3 &= 0° + 5/10(\beta - 0°) \\ \Sigma M_2 &= 0° + 4/10(\beta - 0°) \\ \Sigma M_1 &= 0° + 3/10(\beta - 0°) \\ \Sigma P_1P_2 &= 0° + 2/10(\beta - 0°) \end{aligned}$$

With an incisal guide inclination equal to v, the relation is:

$$\begin{aligned} \Sigma M_3 &= v + 5/10(\beta - v) \\ \Sigma M_2 &= v + 4/10(\beta - v) \\ \Sigma M_1 &= v + 3/10(\beta - v) \\ \Sigma P_1P_2 &= v + 2/10(\beta - v) \end{aligned}$$

The factor d is consequently 5/10 for the third molar, 4/10 for the second molar, 3/10 for the first molar, and 2/10 for the premolars.

TABLE II. CID INCLINE TABLE

CUSP ANGLE (Σ)	CID ANGLE ($\beta - \upsilon$)												
	60°	50°	40°	30°	20°	10°	0°	−10°	−20°	−30°	−40°	−50°	−60°
ΣM_3 ($d = 5/10$)	$\upsilon + 30°$	$\upsilon + 25°$	$\upsilon + 20°$	$\upsilon + 15°$	$\upsilon + 10°$	$\upsilon + 5°$	υ	$\upsilon - 5°$	$\upsilon - 10°$	$\upsilon - 15°$	$\upsilon - 20°$	$\upsilon - 25°$	$\upsilon - 30°$
ΣM_2 ($d = 4/10$)	$\upsilon + 24°$	$\upsilon + 20°$	$\upsilon + 16°$	$\upsilon + 12°$	$\upsilon + 8°$	$\upsilon + 4°$	υ	$\upsilon - 4°$	$\upsilon - 8°$	$\upsilon - 12°$	$\upsilon - 16°$	$\upsilon - 20°$	$\upsilon - 24°$
ΣM_1 ($d = 3/10$)	$\upsilon + 18°$	$\upsilon + 15°$	$\upsilon + 12°$	$\upsilon + 9°$	$\upsilon + 6°$	$\upsilon + 3°$	υ	$\upsilon - 3°$	$\upsilon - 6°$	$\upsilon - 9°$	$\upsilon - 12°$	$\upsilon - 15°$	$\upsilon - 18°$
ΣP_1P_2 ($d = 2/10$)	$\upsilon + 12°$	$\upsilon + 10°$	$\upsilon + 8°$	$\upsilon + 6°$	$\upsilon + 4°$	$\upsilon + 2°$	υ	$\upsilon - 2°$	$\upsilon - 4°$	$\upsilon - 6°$	$\upsilon - 8°$	$\upsilon - 10°$	$\upsilon - 12°$

This table indicates the relation between the sagittal cusp angle (or tilting of cuspless posterior teeth) (Σ) and, respectively, the condylar (β) and the incisal (υ) guide inclinations. The calculation of cusp angles is based on the *cid* angle, which is the difference between the condylar and the incisal guide inclinations ($\beta - \upsilon$) and the fraction of the distance *(d)* from the incisal point to the cusp in question.

M = molar; P = premolar.

The formula may also be expressed $\Sigma = v + \Sigma\ cid$, where *cid* is equal to the angle $\beta - v$. Table II is based on this formula. For example, an incisal guide inclination of 10 degrees and a condylar guide inclination of 40 degrees give the following cusp angulations:

$$\Sigma M_3 = v + d(\beta - v), \text{ where } d \text{ for } M_3 = 5/10$$
$$\Sigma M_3 = 10° + 5/10(40° - 10°) = 10° + 15° = 25°$$

In the same way, the angulation for the rest of the cusps may be calculated:

$$\Sigma M_2 = 10° + 12° = 22°$$
$$\Sigma M_1 = 10° + 9° = 19°$$
$$\Sigma P_1P_2 = 10° + 6° = 16°$$

If the incisal guide inclination is equal to 40 degrees and the condylar guide inclination is equal to 10 degrees, the cusp angulation for M_3 is:

$$\Sigma M_3 = 40° + 5/10(10° - 40°) = 40° + 5/10(-30°) = 40° - 15° = 25°$$

In the same way, the angulation for the rest of the cusps may be calculated:

$$\Sigma M_2 = 40° - 12° = 28°$$
$$\Sigma M_1 = 40° - 9° = 31°$$
$$\Sigma P_1P_2 = 40° - 6° = 34°$$

The values in the tables are approximate. The difference between the approximate values and the exact values is less than 1 degree for *cid* angles up to 60 degrees.[2]

GYSI'S FORMULA FOR THE SECOND MOLAR

Gysi's formula for the angulation of the second molar[3] is:

$$\text{Angulation of } M_2 = \frac{\text{Condyle guide inclination} + \text{Incisal guide inclination}}{2}$$

If the angulation of M_2 is ΣM_2, the condylar guide inclination is β, and the incisal guide inclination is v, the formula will be $\Sigma M_2 = \frac{\beta + v.}{2}$.

Gysi's formula for M_2 is in accordance with Swenson's formula for M_3, where:

$$\Sigma M_3 = v + d(\beta - v) = v + 5/10(\beta - v) = \frac{2v}{2} + 1/2(\beta - v) = \frac{\beta + v}{2}$$

Gysi's formula is assumed to be an empirical formula, giving the dentist a conception of the approximate cusp angulation and the setting of the incisal table of an adjustable articulator.

INFLUENCE OF THE COMPENSATING CURVE OF OCCLUSION

Regarding the culculation of the cusp angle in Table II, the summits of the cusps are assumed to be situated in the plane of occlusion. By means of the compensating curve of occlusion, the cusp angulation may be reduced and still maintain antagonistic contact along the entire length of the facets by protrusive gliding

movements. Taking advantage of the compensating curve, the protrusive facets ought to be reduced correspondingly to the cusp plane angle, which is the sagittal slope of the tooth to the occlusal plane.[4]

Setting cuspless posterior teeth (cusp angulation equals zero degrees) in complete dentures, where the incisal guidance equals zero degrees, the cusp plane angle equals the slope of the cusp angulation according to Table I.[4] The same line of argument is applicable to positive incisal guide inclination. To attain a smooth-running antagonistic contact along the entire length of the protrusive facets by gliding movements of the jaw, the slope of the cuspless posterior teeth may be set in accordance with the cusp angulation in Table II.

SUMMARY AND CONCLUSION

The relation between the incisal guide inclination (v), the cusp angulation (Σ), and the condylar guide inclination (β) can be expressed by the formula $\Sigma = v + d(\beta - v)$, where d (the fraction of distance from the incisal point) has values for the respective cusps of $M_3 = 5/10$, $M_2 = 4/10$, $M_1 = 3/10$, and $P_1P_2 = 2/10$. The exactness of the formula is approximately $\pm$ 1 degree for differences between the condylar guide inclination and the incisal guide inclination until a difference (*cid* angle) of 60 degrees is reached. To attain balanced occlusion by using cuspless posterior teeth, it is necessary to regard the entire occlusal surface of the cuspless tooth as one single protrusion facet and set up the teeth accordingly.

REFERENCES

1. Swenson, M. G.: Complete Dentures, ed. 2, St. Louis, 1947, The C. V. Mosby Company, p. 249.
2. Christensen, F. T.: Cusp Angulation for Complete Dentures, J. Pros. Den. **8**:910-923, 1958.
3. Gysi, A.: Kieferbewegung und Zahnform, *in* Scheff and Pichler, editors: Handbuch der Zahnheilkunde, Berlin and Vienna, 1929, Urban and Schwarzenberg, vol. IV, p. 127.
4. Christensen, F. T.: The Compensating Curve for Complete Dentures, J. Pros. Den. **10**:637-642, 1960.

Kannikgaten 13
Stavanger, Norway

RE-EVALUATION OF POSTERIOR TOOTH FORMS FOR COMPLETE DENTURES

M. B. Sosin, D.D.S.
Los Angeles, Calif.

THE NATURAL DENTITION has been used as a guide, almost as a matter of course, to design artificial posterior teeth for complete dentures. Yet, it is known from clinical experience that dentures function during mastication only in a limited degree compared to the natural dentition. Is it not possible, then, that a new approach in our thinking might lead to a solution of the problems with which dentists are beleaguered?

The purpose of this article is to re-evaluate the concept that, for mastication, the natural posterior tooth form is the ideal form to be used in the construction of complete dentures.

NATURAL TEETH

The superb dentition with which man has evolved consists of a sturdy cuspal arrangement of hard enamel in the crown and a long, strong root that is usually about two and one-half times the length of the crown (Fig. 1). This root is deeply embedded in sturdy bone and investing tissues (Fig. 2).

The occlusal surface of the crown has evolved simultaneously with its accompanying supporting mechanism. They form an inseparable combination, each of which could not have developed without the other.

During mastication, the crown-root combination allows man to exert over 100 pounds of pressure comfortably. This amount is well within biologic needs. The pressure is shared by the crown, the root, the periodontal membrane, the lamina dura, and the cancellous bone.

The limit of hardness of a bolus that the natural dentition can resist comfortably is controlled by the neuromuscular mechanism, the tactile sense of the periodontal membrane, and other oral tissues. So vital is this control that, when it is lost, excess muscle power may cause a fracture of a tooth without the knowledge of the patient.

ARTIFICIAL TEETH

In complete dentures, the resistance to the bolus is transmitted from the artificial tooth, through the denture base to the mucosa and connective tissue, and finally to a portion of the outer surface of the mandibular and maxillary residual ridges. The brunt of the force is received first by the mucosa. Being primarily a covering tissue not designed for such heavy impact, the mucosa becomes readily displaced and contused. This is a common clinical observation. That the underlying

Fig. 1.—Relatively massive root support accompanies the occlusal surface form of the natural teeth.

bone can, by itself, carry much greater loads is evidenced when the implant technique is used. When mucosa and connective tissue are interposed between bone and denture base, the ability to penetrate a bolus is sharply reduced. The load-bearing capacity of mucosa is no more than 20 pounds in many older people. Furthermore, in complete dentures the tactile sense and neuromuscular control are sharply limited. Limited load-bearing capacity of the mucosa and loss of periodontal tactile sense together explain most of the discomfort experienced by patients during mastication.

DESIGNING A POSTERIOR TOOTH

The occlusal surfaces of artificial posterior teeth designed in the usual manner are blunt. Therefore, a considerable force is required to drive artificial teeth through a bolus of food. In turn, the bolus offers considerable resistance to the occlusal surfaces. Once we recognize the basic difference between the natural and artificial dentition, we must design an occlusal form which penetrates the bolus with greater ease, thereby putting less stress on the bearing mucosa.

Fortunately, posterior occlusal surfaces are not visible under normal circumstances and esthetics is not a serious consideration. We may concern ourselves only with designing the most efficient device (tooth) regardless of the final shape it takes.

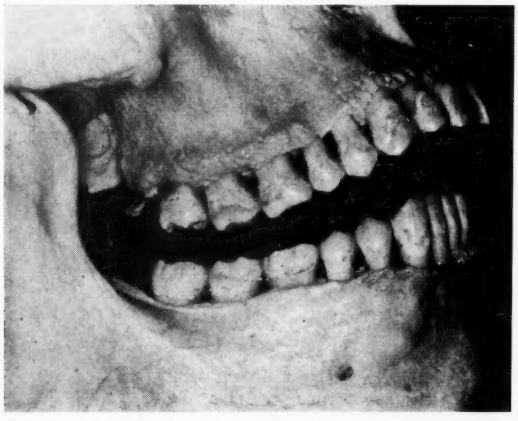


Fig. 2.—Sturdy bone support accompanies occlusal surface form of the natural teeth.

The pressure per unit area varies inversely with the surface of the contact area. Therefore, to allow the 20 pounds of load-bearing capacity of mucosa to approximate in efficiency the more than 100 pound capacity of the natural dentition, we need to design a compressing surface of one-fifth or less the area of the natural occlusal surface.

The smallest surface is a point. However, a point only punctures. A series of points in a straight line forms a blade, and a group of blades en masse becomes a mallet. A mallet is merely a repetition of the natural tooth form. Therefore, the design of choice is a blade or arrangement of blades which can be made to cut and shred and which can be set in balanced occlusion to a given set of maxillomandibular relationships (Fig. 3).

BLADE MECHANISM TECHNIQUE

The maxillary and mandibular bicuspids are arranged for function. Then, the maxillary first and second molars and second bicuspids are replaced by six blades cast in Vitallium. The blades are constant in design for all patients (Fig. 4). The maxillary and mandibular dentures are processed, returned to the articulator (split cast), and milled to fully meet the requirements of the adjustable articulator (Fig. 4, *C*).

With the dentures on the articulator, inlay wax is built up on the mandibular denture base distal to the bicuspids on the right and left sides (Fig. 5). Articulator movements are made, and the maxillary blades cut a series of tables in the inlay wax

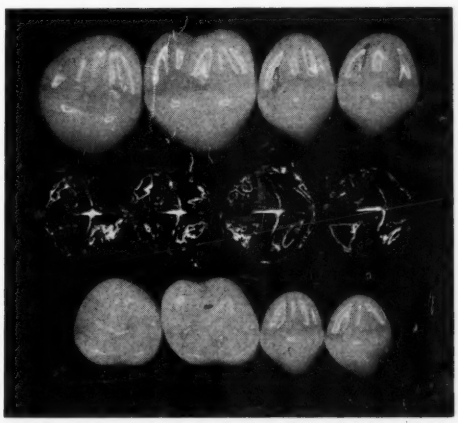


Fig. 3.—Blade-designed occlusal surfaces are compared to those copied from natural teeth.

(Fig. 6). The curvature of the tables incorporates the condylar inclination, the Bennett movement, and the horizontal and vertical overlap. The full envelope of motion in balanced occlusion is created and preserved.

The wax tables, having been previously keyed and lubricated, are carefully removed. The tables are cast in Vitallium and are designed differently for each patient (Fig. 7).

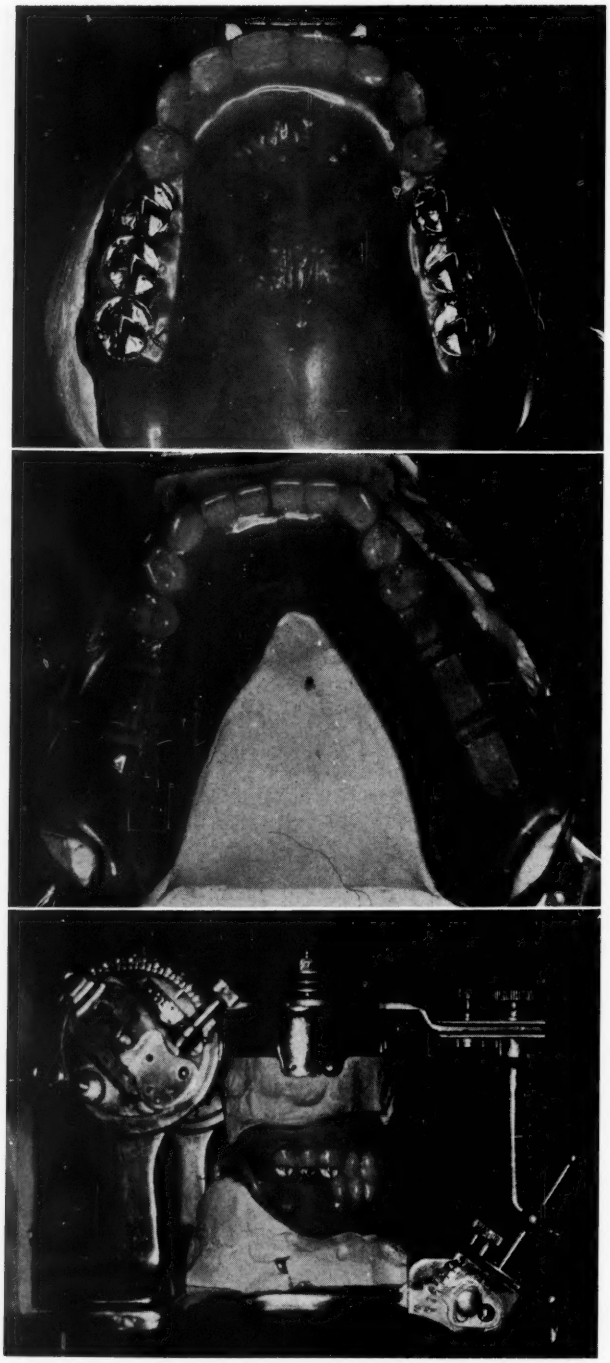


Fig. 4.—*A*, Blades of constant design are used on the upper denture. *B*, Key locks are formed on the lower denture base and are used to attach the blades to the lower denture base. *C*, The dentures are milled on the articulator so that all of the porcelain teeth are in balanced occlusion.

The tables are returned to the lower base and attached to it by means of cold-curing acrylic resin (Fig. 8). A further check is made on articulator excursions before the dentures are removed from the instrument (Fig. 9).

RESULTS

Twenty-five complete dentures have been built using the blade mechanism. Examination of the patients' mouths revealed little if any evidence of trauma of the

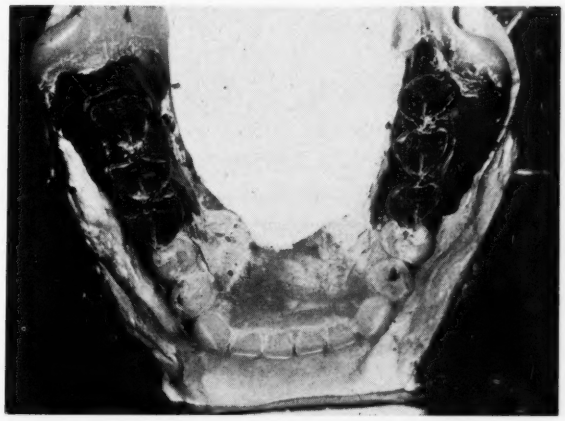


Fig. 5.—Wax tables are developed in the lower denture base in inlay wax. This is done on the articulator.

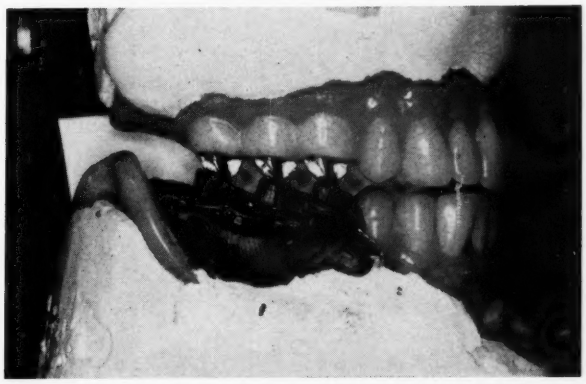


Fig. 6.—Protrusive balancing contacts in the inlay wax are developed on the articulator.

mucosa. Injury to the tongue and cheeks has not been observed. The patients are happy and are able to enjoy a much wider range of foodstuffs than had been possible with previous dentures. Appearance has not been a problem.

The argument "enter bolus, exit balance" holds true for a much shorter time than with the natural form of artificial posterior tooth because the penetration of food is easier, quicker, and more comfortable. Also, friction between the working

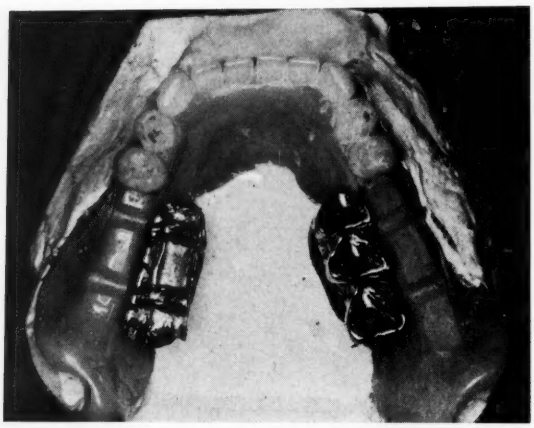


Fig. 7.—The lower tables are cast. They are of a different design for each patient.

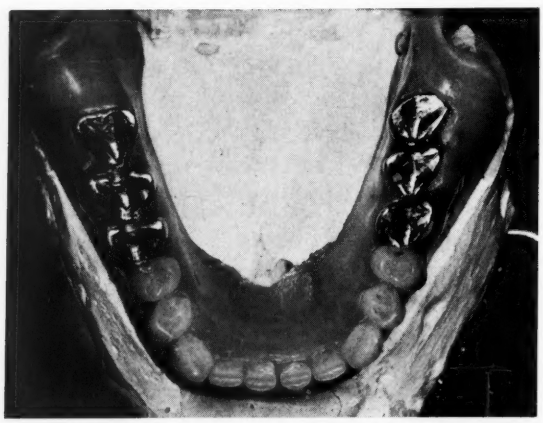


Fig. 8.—The metal tables are attached to the lower denture base with cold-curing acrylic resin.

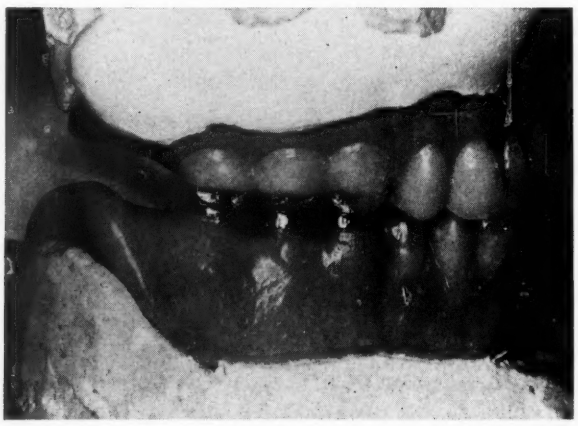


Fig. 9.—The occlusion is rechecked after the tables are attached to the denture base.

surfaces of the maxillary and mandibular teeth is greatly reduced since metal to metal contacts create less drag on the mucosa (especially during bruxism) than do porcelain to porcelain contacts.

Only one design of blades has been employed. There is no doubt that other, perhaps more successful, designs can be developed to answer the problem to an even greater degree. It is hoped that this experiment will stimulate further thinking and effort in this direction.

SUMMARY

The stresses from the occlusal surfaces of the teeth in an edentulous mouth must be borne by the mucosa rather than the investing tissues as in the natural dentition. The limited load-bearing capacity of the mucosa renders natural form occlusal surfaces inadequate for mastication of many foods.

It has been clinically demonstrated that a radically different occlusal surface provides an acceptable answer to this problem. The occlusal surface is composed of an arrangement of blades in the upper denture that function against carefully articulated tables in the lower denture.

6333 Wilshire Blvd.
Los Angeles 48, Calif.

APPLICATION OF MINIATURIZED ELECTRONIC DEVICES TO THE STUDY OF TOOTH CONTACT IN COMPLETE DENTURES

A Progress Report

ALLEN A. BREWER, D.D.S.,* AND DONALD C. HUDSON, D.D.S.**
School of Aviation Medicine, Brooks Air Force Base, Texas

A METHOD FOR STUDYING tooth contacts in complete dentures by means of radio signals has been developed. Both masticating and nonmasticating contacts can be studied without creating an abnormal situation. Not much work has been done by this method since it is so recent; it shows promise, however, and other investigators may want to adopt the procedure.

This method was developed by team effort at the USAF School of Aviation Medicine. Knowledge acquired during the development of telemetering equipment for monitoring space flight was adapted to research in clinical dentistry. The electronics section of the physiology department designed a small radio transmitter to telemeter to earth the heart beat of a mouse sent aloft in a space capsule. We learned that this transmitter could be built into complete dentures so that any tooth contact or combination of tooth contacts would send a signal. Our first experiment utilized the same circuitry as that developed for the mouse biopack.

The audiology department then altered a hearing aid amplifier to make a keying device which would register these signals.

The School of Aviation Medicine instrument shops then modified a pocket watch to make a portable event counter.

NEED FOR THE STUDY

No agreement.

During the past few years, a number of investigators have studied tooth contacts during mastication. They all embedded metal contacts in the teeth and led connecting wires from the mouth to recording equipment.

Jankelson, Hoffman, and Hendron[1] concluded that tooth contact during mastication was negligible and nonfunctional and that only during deglutition did tooth contact occur functionally. Their records were made by means of an electrocardiograph. They assumed that deflections of the writing pen smaller than those made by tapping the teeth together indicated a leakage of electrical current through the food sample.

The opinions and assertions contained in this article are the private ones of the authors and are not to be construed as official or reflecting the views of the Department of the Air Force.

*Head, Prosthetics Section, Department of Dental Sciences.
**Chief, Department of Dental Sciences.

Yurkstas and Emerson[2] published the results of a similar method with 12 subjects who wore artificial dentures, all with zero degree teeth. All of these patients, during mastication, exhibited considerable contact of teeth on the working side and almost 100 per cent contact on the balancing side.

Anderson and Picton[3] reported the results of a series of experiments on 10 subjects with natural dentitions, using an oscilloscope to record contact through alloy fillings, in the centric occlusion position only. These signals came from the nonworking side, because the wires interfered with chewing when extending from the working side. They found that, in most subjects, teeth came into contact for more than half the chewing thrusts.

The wide difference in results obtained in these three separate investigations prompted this study.

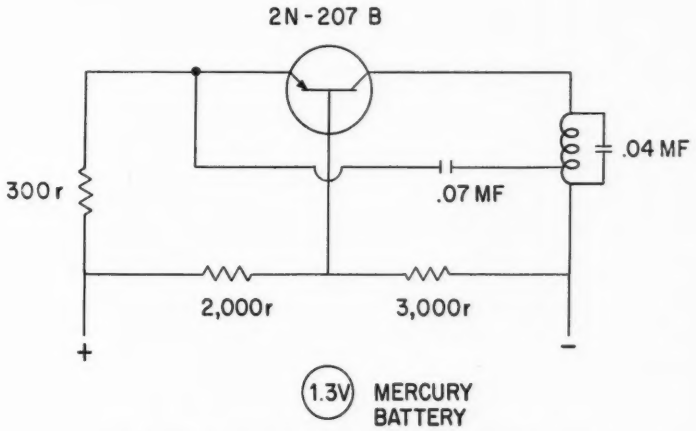


Fig. 1.—The transistor oscillator circuit and values.

INSTRUMENTATION

Transmitter.—All components are available commercially. A transistor, a capacitor, three resistors, and a scramble wound coil for inductance are connected in a conventional feedback oscillator circuit. The values of the components may be seen in the circuit diagram (Fig. 1). The tuned inductance obtained by shunting with miniature capacitors of 0.01 to 0.04 μfd determines the frequency. Although these transistors will work successfully at higher frequencies, 40 kc. is used. This reduces the possibility of outside interference.

The transmitter is powered by a 1.3 v. mercury battery connected so that any desired tooth contact or combination of tooth contacts will close the circuit, resulting in a signal. The size of the miniature components is indicated in Fig. 2.

Recording Equipment.—The signal is picked up by an antenna tuned to the same frequency as the transmitter. Although an untuned antenna can be used, resonating it at the operating frequency results in better energy transfer and a more efficient unit. This antenna is designed to fit around the neck, under the shirt (Fig. 3).

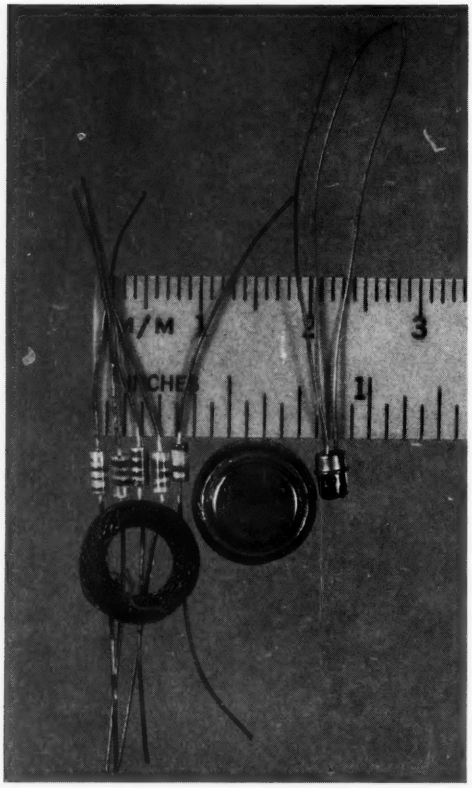


Fig. 2.—The components for the transistor oscillator. Note the small size.

The signal as picked up by this receiving antenna may be amplified by a commercial hearing aid amplifier powered by a 1.3 v. mercury cell. This signal may be observed on a standard vacuum tube voltmeter or on a cathode ray oscilloscope. The time sequence and duration of contacts can be recorded on a standard electrocardiograph.

The addition of a single stage transistor amplifier and 30 v. more will activate the portable watch type event counter.

This pocket size counting device was made for the subject to use while he engaged in day or night activities other than eating. The balance wheel of a pocket watch was removed and an escapement control was custom made by use of a lever activated by an electromagnet (Fig. 4). In this particular watch, 112 contacts or signals are required to advance the hands 1 minute. The entire amplifying and counting unit is small enough to be carried conveniently in the shirt or pajama pocket (Fig. 3).

Cost.—The total cost of the components for each transmitter is about $8.00. There is apparently no wear on the transmitter components. Estimated transmitter battery life under normal use is several years. The battery can be replaced without interfering with the rest of the circuit. The hearing aid amplifier cost is about $50.00, and the watch conversion is custom work.

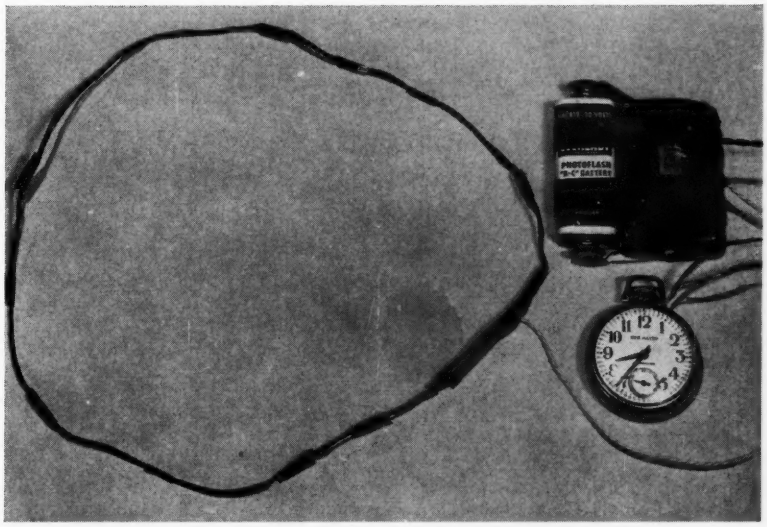


Fig. 3.—The pick-up coil and portable pocket counter.

Fig. 4.—The balance wheel of the watch was removed. Escapement is controlled by a solenoid-activated lever.

INCORPORATION INTO DENTURES

Gold occlusal surfaces are cast and arranged to occlude on dentures as desired. Any area or combination of areas may be selected to send a signal upon contact with opposing areas.

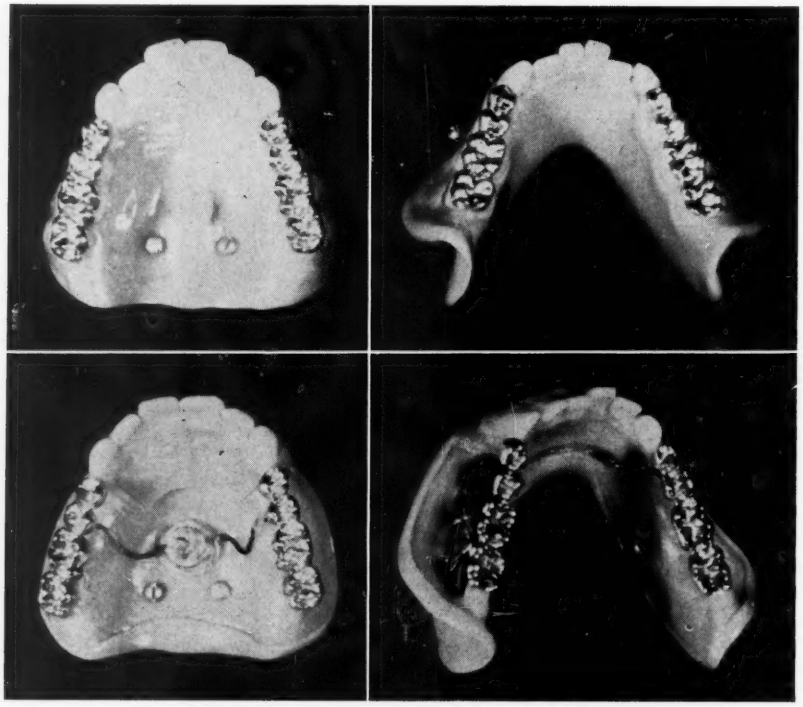
The transmitter components may be spread throughout the dentures wherever space is available (Fig. 5). The transmitter is then enclosed with autopolymerizing acrylic resin. The weight of the complete unit is less than that of the material it replaces. Patients who were tested noticed a slight metallic taste for the first few days, but they soon became accustomed to this and were no longer conscious of it.

The completed dentures are no different in size, shape, weight, or sensation than conventional complete dentures with gold occlusal surfaces (Fig. 5).

PROCEDURES AND RESULTS

Since we have tested only 2 patients to date, we hesitate to draw any definite conclusions as to just when and how teeth contact. We have done enough, however, to show that tooth contact in chewing does vary with the individual and with the type and arrangement of cusp form. The type of food eaten also influences the number of tooth contacts.

A.



B.

Fig. 5.—*A*, Completed test dentures containing miniature radio transmitter. *B*, Cutaway showing placement of electronic components.

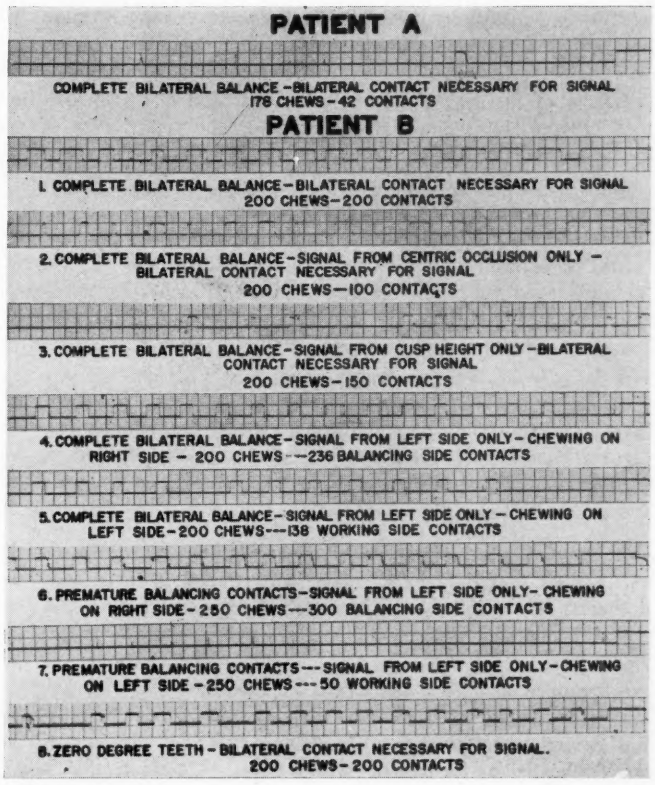

PATIENT A
COMPLETE BILATERAL BALANCE - BILATERAL CONTACT NECESSARY FOR SIGNAL
178 CHEWS - 42 CONTACTS
PATIENT B
1. COMPLETE BILATERAL BALANCE - BILATERAL CONTACT NECESSARY FOR SIGNAL
200 CHEWS - 200 CONTACTS
2. COMPLETE BILATERAL BALANCE - SIGNAL FROM CENTRIC OCCLUSION ONLY - BILATERAL CONTACT NECESSARY FOR SIGNAL
200 CHEWS - 100 CONTACTS
3. COMPLETE BILATERAL BALANCE - SIGNAL FROM CUSP HEIGHT ONLY - BILATERAL CONTACT NECESSARY FOR SIGNAL
200 CHEWS - 150 CONTACTS
4. COMPLETE BILATERAL BALANCE - SIGNAL FROM LEFT SIDE ONLY - CHEWING ON RIGHT SIDE - 200 CHEWS - 236 BALANCING SIDE CONTACTS
5. COMPLETE BILATERAL BALANCE - SIGNAL FROM LEFT SIDE ONLY - CHEWING ON LEFT SIDE - 200 CHEWS - 138 WORKING SIDE CONTACTS
6. PREMATURE BALANCING CONTACTS - SIGNAL FROM LEFT SIDE ONLY - CHEWING ON RIGHT SIDE - 250 CHEWS - 300 BALANCING SIDE CONTACTS
7. PREMATURE BALANCING CONTACTS - SIGNAL FROM LEFT SIDE ONLY - CHEWING ON LEFT SIDE - 250 CHEWS - 50 WORKING SIDE CONTACTS
8. ZERO DEGREE TEETH - BILATERAL CONTACT NECESSARY FOR SIGNAL.
200 CHEWS - 200 CONTACTS

Fig. 6.—Tracings made on the electrocardiograph showing the number and duration of tooth contacts during eating of a hamburger sandwich. Each section represents 12 seconds.

Patient A.—A 40-year-old man—a complete denture wearer for 3 years—presented with adequate record models, pre-extraction roentgenograms (complete mouth), and pre-extraction photographs. The story these records told, together with the patient's history, combined to paint a picture of a very poor natural dentition.

New complete upper and lower dentures were constructed for this patient. An arbitrary face-bow mounting was used to transfer the upper cast to a Hanau model H articulator. An accurate centric relation record was used to complete the mounting of the casts on the instrument. A protrusive record in stone was used to set the protrusive condyle paths, and the posts were set at 15 degrees lateral inclination. Although the tooth relationship had been class II in the natural dentition, the anterior teeth were positioned in a normal relationship for esthetic reasons. Thirty degree porcelain cusp teeth were used and set in complete bilateral balance, both cross tooth and cross arch. The left posterior teeth were arranged in a cross-bite relationship.

At the time of insertion, the dentures were remounted on the articulator in protrusive right lateral and left lateral positions successively, using hydrocolloid (fast setting) as the registration medium. With the instrument used as a tripod, the interferences in the occlusion were removed after each remounting.

After the patient had worn these dentures comfortably for 1 month, they were duplicated with the posterior occlusal surfaces cast in gold as quadrant units. The transmitter was built into the dentures as in Fig. 5, and the wiring was connected so that simultaneous contact of points in the posterior occlusion on *both* sides was required to send a signal.

The first day this patient wore the new dentures, he exhibited more than 1,500 nonmasticating contacts per hour. As he continued to wear them, however, this number was reduced to an average of 150 contacts per hour (nonmasticating waking contacts).

Masticating contacts of this patient were tested with many foods, and he exhibited few and fleeting contacts. Fig. 6 shows the type of contacts. The spiked type of deflection of the writing stylus on the paper is the result of a fleeting contact of the teeth. The duration of contact is measured from the start of the rise from the base line to the start of the return from the height of the deviation from the base line (Fig. 7, *A*).

These same deflections may be reproduced on the electrocardiograph by rapid tapping together or sliding of the teeth on the articulator or in the mouth.

In chewing a hamburger sandwich, the patient used 178 chewing strokes (counted) and exhibited 42 tooth contacts, 17 of these the result of swallowing. That these were true metal to metal contacts and not current leakage through food and saliva was verified in the following manner:

Food was placed between the teeth and pressure was exerted. No signal resulted until the food was penetrated by a cusp or cusps and metal to metal contact resulted. This was accomplished with the dentures on the articulator and repeated with the dentures in the mouth.

The same tests were repeated with wet Kleenex and with saliva-moistened filter paper. Again no signal ensued until the material was perforated and metal to metal contact resulted.

Patient B.—This man, 38 years of age, had become edentulous at the age of 14. He wore the complete dentures fitted at that time for 5 years. Subsequent dentures continued to give him satisfactory service until he was 30 years of age. In the 8 years before the present treatment, he had worn twelve different sets of complete dentures and was quite unhappy with all of them.

New complete dentures were made for this patient by the same procedures as for patient A. The teeth were arranged in normal occlusion, because the ridge relationship was excellent. Complete cross tooth and cross arch bilateral balance was provided, and the occlusion was corrected at time of insertion, as for patient A. After a month of continuous comfortable wear, these dentures were duplicated, as for patient A.

The electrical current leakage was checked as before and found to be negative. Although chewing with many foods was tested, the hamburger sandwich presents a fairly representative picture of the pattern of masticating contacts.

This patient, in chewing one hamburger sandwich, used an average of 200 chewing strokes (counted) and registered 200 contacts (Fig. 6). He brought his teeth together on every chewing stroke. The only food that we could feed him that did not show tooth contact was salted crackers. Over a period of several months this patient averaged 600 to 800 contacts for a normal meal, 150 contacts per hour waking nonmastication, and 40 contacts per hour while sleeping. The average chewing contact was 1/5 second, the swallowing contact 1 second. He would, therefore, normally have the teeth together about 10 minutes in a 24 hour period. There were sleeping periods, however, in which he exhibited more than 1,500 contacts per hour in a 7 hour period. This would mean a contact was made almost every other second or almost 2 hours of contact in one night.

Inasmuch as this patient showed so many more masticating contacts than the previous patient, we thought that we might have infringed on the free-way space (interocclusal distance).

Effect of decreased vertical dimension: Another set of dentures was made in the same manner, but the vertical dimension was decreased 5 mm. at the central incisor region. Now, a similar hamburger sandwich was eaten with 200 chews and 300 contacts were exhibited (Fig. 7, *B*). This seemed rather surprising, so we resorted to a subjective reaction from the patient to try to explain this. The patient felt that he had to work harder to chew his food. After these dentures were worn for a week, however, the number of masticating contacts leveled off so that they were the same in number, duration, and sequence as with the dentures with less interocclusal distance. In other words, the patient adapted to this new situation. Herein lies the value of this method of investigation. This is not a laboratory experiment. The patient can wear the dentures long enough to become accustomed to them and we can record the contacts constantly.

It appeared that the patient was using more than a simple vertical chewing stroke, as indicated by the 300 contacts for 200 chews, so dentures were made that sent a signal from the centric relation–centric occlusion position only (Fig. 8, *A*).

Contacts in centric occlusion: A hamburger sandwich now required 200 chews but showed only 100 contacts. This seemed to indicate that half of the contacts were made on cusp inclines or at cusp height. However, food packing in the central fossae of the posterior teeth may have prevented contact. Therefore, another set of dentures was made that would send a signal from the cusp height only (Fig. 8, *B*).

Contacts on cusp tips: A hamburger sandwich still required 200 chews but indicated an average of 150 contacts. More contacts, but shorter ones, occurred at the cusp height than at the centric position.

Contacts when chewing on one side: Next, we made dentures which sent the signal when only the left side was in contact. The lower left quadrant was split between the bicuspids and molars (Fig. 9). This then required the contact of at least a molar and a bicuspid on the left side before a signal would result. The patient still chewed the same number of times for a hamburger sandwich. As he chewed on the right side, he indicated 236 balancing contacts. As he chewed on the left, he indicated 138 working side contacts (Fig. 6). This type of chewing was an effort for the patient as he was ordinarily a simultaneously "bilateral" chewer.

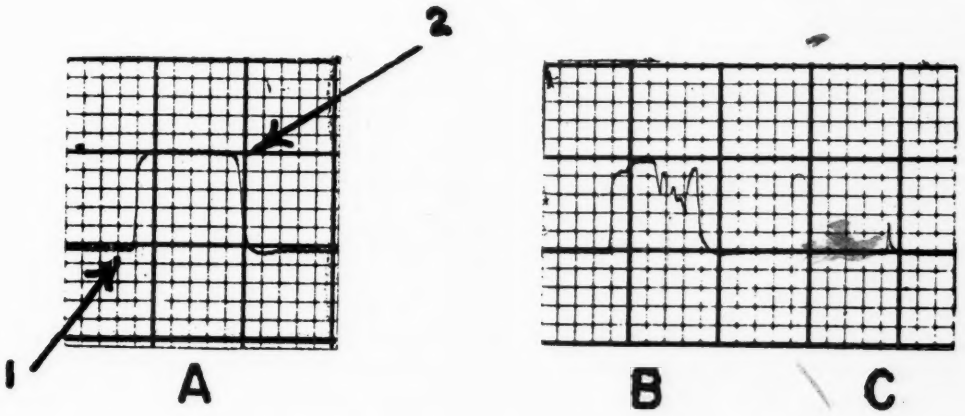


Fig. 7.—Enlarged sections of the tracings made on the electrocardiograph. *A*, The distance from arrow *1* to arrow *2* indicates the duration of a contact. Since each large square represents approximately 1/5 second, this contact was approximately 1/5 second in duration. *B*, A rapid make and break of contact on a chewing stroke. The same type of tracing may be produced by rubbing the dentures together in the hand or in the mouth. *C*, A very fleeting contact of about 1/100 second. The deviation does not have to reach the common height to indicate contact as the machine does not keep pace with too rapid an action.

Excessive balancing contacts: Next, the same type of denture was made but with premature balancing contacts on both sides. The signal came when only the left side was in contact. This was the only set of dentures in which the number of chewing strokes was appreciably increased (by approximately 25 per cent—250 chews for a hamburger). The balancing contacts increased to 300, and the working contacts decreased to 50 (Fig. 6). This seems to show that the cusp height is used in mastication. It also verifies the absence of current leakage through food and saliva.

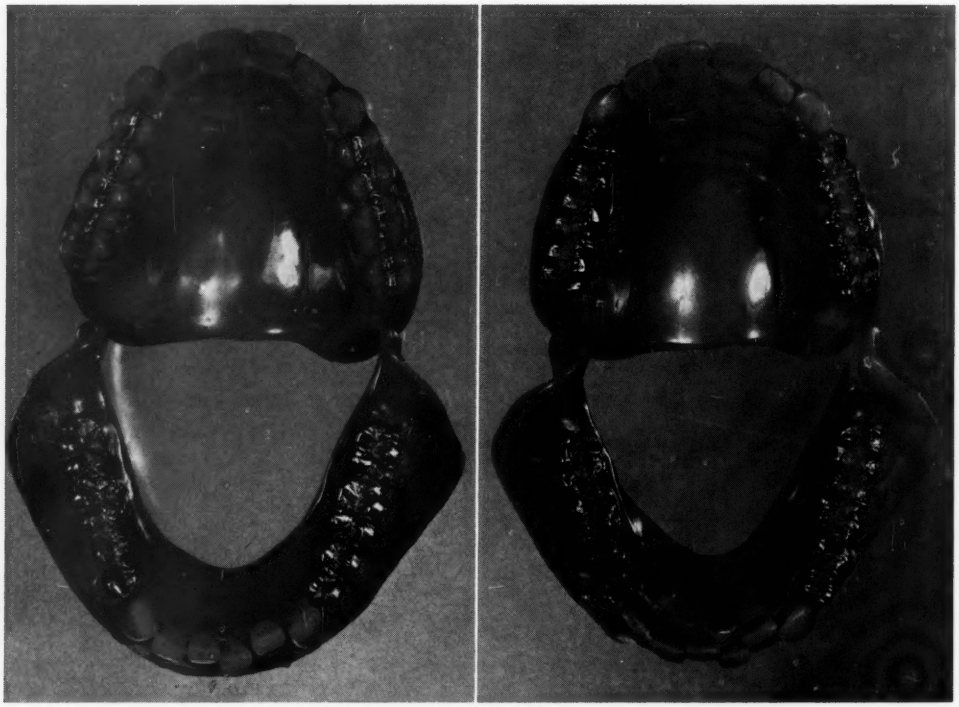
Zero degree cusps: Next, dentures were constructed with zero degree cusps and again required contact on both sides of the arch to send a signal. Tests showed that 200 chews were again used to eat a hamburger sandwich, and 200 contacts were indicated.

INTERPRETATION OF FINDINGS

Under the conditions of this experiment, teeth do contact in chewing. Evidently the chewing habits established with the natural dentition are carried over to complete dentures. Patient A had for years, possibly because of his physical make-up, possibly because of his poor natural dentition, chewed in a very slow, cautious manner. He continued to do this with complete dentures and relinquished the chewing pressure whenever the teeth came close to contact.

Patient B, however, chewed with great force. This was true regardless of the type of cusp form, tooth relationship, or degree of "balance" that we provided for him.

It does appear that contact occurs on the cusp height as well as in the centric relation–centric occlusion position.



A. *B.*

Fig. 8.—Completed test dentures. Both dentures require simultaneous bilateral contact to evoke a signal. *A*, A signal results from contact in the position of centric relation only. *B*, A signal results from contact at the cusp height only.

Premature balancing contacts definitely interfere with bringing the teeth together on the working side. When the patient is a forceful chewer, cusp teeth should be well balanced.

Subjectively, patient B reacted to the various dentures as follows:

He preferred the dentures made with cusp teeth in complete bilateral balance and with a normal interocclusal distance. The dentures with premature balancing

contacts did distress him. He complained about "interference" in chewing. The zero degree teeth "do not seem to cut up the food as well." The lack of anisognathism interfered with his normal biting pattern. He complained because of a "lack of a definite place to close my teeth."

The patient's sleeping contacts seemed to increase as a result of a "frustrating day."

FURTHER INVESTIGATIONS

Patient A was lost for a time because of a change in station. He is available again for further study. We plan to repeat for him many of the situations created for patient B.

Each situation created points out new areas for study. The study of more patients will result in a more comprehensive picture of both masticating and non-masticating tooth contacts.

The possibilities for further work in this field are limited only by the imagination and the technical effort brought to bear on this problem. Industry is developing new, smaller, and better electronic components so rapidly that by the time we have completed a unit it may be obsolete. Engineers assure us that the new tunnel diodes will make possible a transmitter small enough to fit into a restoration in a

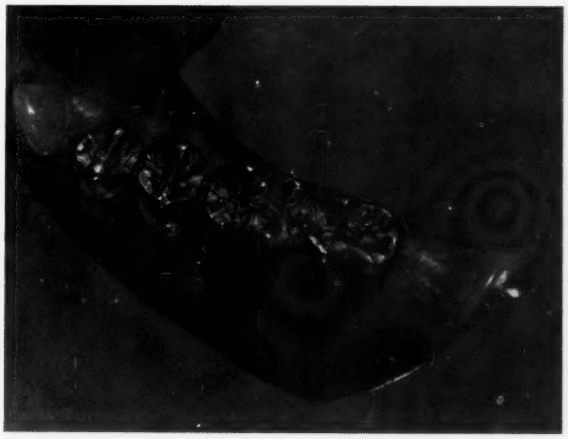


Fig. 9.—The left side of a mandibular test denture showing the break in the occlusal segment between the bicuspid and molar areas. Points on the bicuspids *and* the molars would have to contact the opposing maxillary quadrant to result in a signal.

single natural tooth. From this single unit, powered only by the current generated by dissimilar metals in saliva, we should be able to determine when the teeth contact, with how much force, and the direction from which the force originates.

Pressure can be utilized to vary the inductance. This change in inductance modulates oscillation frequency. An FM receiver will demodulate the signal and produce an output voltage proportional to the original pressure variations. The

output could be recorded on a standard oscillograph. Eventually we may be able to check occlusion much as we check heart action with an electrocardiogram.

SUMMARY

A method has been developed for incorporating radio transmitters into complete dentures for the study of masticating and nonmasticating contacts of the occlusal surfaces. Both fixed and portable equipment may be used to record these contacts in the laboratory and during normal activities at any time.

In the pilot study outlined on 2 patients, patient A exhibited few and fleeting contacts of the teeth in chewing. Patient B exhibited a great deal of tooth contact in chewing most foods. The number and character of the contacts were influenced by the type of cusp form and the harmony of balanced occlusion. The signal came from the cusp height as well as from the centric relation–centric occlusion position.

The potentiality of this method in dental research will be greater as new electronic devices are perfected.

REFERENCES

1. Jankelson, B., Hoffman, G. M., and Hendron, J. A.: The Physiology of the Stomatognathic System, J.A.D.A. **46**:375-386, 1953.
2. Yurkstas, A. A., and Emerson, W. H.: A Study of Tooth Contact During Mastication With Artificial Dentures, J. Pros. Den. **4**:168-174, 1954.
3. Anderson, D. J., and Picton, D. C. A.: Tooth Contact During Chewing, J. D. Res. **36**:21-26, 1957.

School of Aviation Medicine, 2317
USAF Aerospace Medical Center (ATC)
Brooks Air Force Base, Texas

NUTRITION FOR SENESCENT DENTURE PATIENTS

CHESTER PERRY, D.D.S.*
University of Detroit, School of Dentistry, Detroit, Mich.

THERE IS NO SEPARATION of good physical health and good dental health. A diseased body contributes to a diseased dental state, and conversely, a diseased dental state often leads to a diseased or malnourished body.

The processes of affording the body adequate substances for growth and support are not simple. They involve chemical, physical, and even mental reactions, many of which are still a mystery to scientists.

Diet and nutrition are often confused. Diet refers to the ingestion of food; nutrition results in the building and repair of body tissues through the assimilation of food particles into living tissue. Adequate nutrition plays a large part in health and contributes to the successful wearing of dentures. However, there are some persons who may be able to masticate food properly but whose digestive systems prevent proper absorption. Therefore, digested food substances, including vitamins and minerals, must be correctly assimilated.

Several important requirements must be considered to ensure adequate nutrition: (1) establish a proper diet, which provides the needed substances for body building, (2) supplement the diet with vitamins and minerals, and (3) emphasize the importance of proper exercise, rest, and, when necessary, medical assistance. If these rules are followed, particularly for older denture patients, the equilibrium between bone resorption and bone formation of the residual ridges will be maintained.

NUTRITION IS NOT DEPENDENT ON NATURAL TEETH

Patients must be informed that they may be well nourished without natural teeth and that dentures will not affect their general health. In fact, dentures may contribute to better utilization of food substances even though new dentures and tender gums may necessitate a change from fibrous to semisolid and softer food substances. Fortunately, semisolid or even liquid foods can supply all the essential elements necessary for good nutrition. Food liquefiers contribute greatly to nutrition while patients are becoming accustomed to new dental prostheses.

As the patient becomes more proficient in the use of new teeth, he may change gradually to the solid and even to fibrous foods. Tender gums may result, in part, from a low pain threshold of the elderly patient. The innervation of the blood vessels in the mucoperiosteum may add to the tenderness.

Read before the Florida State Dental Association, Hollywood, Fla.
*Assistant Professor, Denture Prosthesis.

SUPPLEMENTARY NUTRITION

Foods that are rich in proteins, minerals, and vitamins are essential to the reparative process of the dental ridges because they minimize vertical, buccal, and lingual ridge resorption.

Nutritionists have developed a list of seven basic foods which should comprise the daily diet, particularly when eating may be generally difficult. This list includes (1) leafy green or yellow vegetables, (2) citrus fruits, (3) potatoes, (4) milk, cheese, and dairy products, (5) meat, poultry, fish, eggs, dried peas, and beans, (6) bread, flour, and cereals (whole grain or enriched), and (7) butter or fortified margarine.

Grain, cereal, and vegetable proteins are insufficient when not utilized particularly in conjunction with animal proteins. For example, milk on cereal greatly increases the availability of the protein in cereal. The basic seven provide an excellent scheme for a daily diet unless the patient is suffering from an organic illness or is under prescribed dietary advice from his physician. The following foods are recommended:

1. Well-cooked cereals: oatmeal, corn meal, Wheatina, and Cream of Wheat.
2. Stewed fruits: peaches, apples, prunes, and apricots.
3. Fresh fruits: crushed apples, pears, bananas, avocado pears, and oranges.
4. Soups: rice, spaghetti, vegetable, and cream.
5. Cooked vegetables: peas, potatoes, spinach, carrots, squash, beets, asparagus, turnips, and Brussels sprouts.
6. Uncooked vegetables: finely cut lettuce, parsley, watercress, and tomatoes.
7. Fish: boiled, broiled, or baked.
8. Eggs: poached, boiled, or scrambled.
9. Ground meats: beef, lamb, and liver.
10. Cheese: cottage, cream, Swiss, and cheddar.
11. Desserts: custards, ice cream, tapioca, and rice puddings.
12. Drinks: sweet milk, skimmed milk, buttermilk, malted milk, eggnog, beef consommé, and orange, pineapple, tomato, and vegetable juices.

The pleasure derived from smelling, tasting, and mixing food with mouth secretions is part of Nature's scheme of digestion. All foods should be mixed in the mouth and tasted. Many older patients claim their new dentures impair their taste. These patients need to be told that none of the end organs of taste are covered by their dentures and they can still taste all flavors. They should also be told that the sensation of taste telegraphs the rest of the digestive system to prepare for what is on the way. The stimulation of the flow of digestive juices in the stomach and other parts, even before food is swallowed, is a function of the receptive mechanism of the nervous system.

NUTRITION AND HEALTH

The aging process may begin as early as the twenties or thirties in some patients. However, aging need not lead to a sad, tired, inactive existence. With the aid of synthetic vitamins, this period may be active, productive, and enjoyable.

Spies[1] and his associates screened 5,000 chronically ill persons of whom 893 were so feeble they had not worked for years. Complete clinical and laboratory diagnoses excluded tuberculosis, heart disease, or any of the easily recognized chronic illnesses. The complaints of the patients masqueraded under symptoms of digestive, nervous, and mental ailments. The youngest in the group was 30 years of age. These patients were fed diets rich in proteins, natural vitamins, and minerals, supplemented with large doses of synthetic vitamins. Dried brewer's yeast powder and liver extracts were added to furnish chemicals still unknown. It is believed these key chemicals are fundamental to the healthy activity of body cells. The result of Spies' experiment was the rehabilitation of many persons through supplementation of the diet with essential materials.

Many studies have been made on the treatment of cardiovascular disease, including coronary occlusion, strokes, and kidney disease on the basis of dietary treatment and supplements. The relationship of these diseases to the activity of the liver and other metabolic processes has placed this subject uppermost in the research of many persons.

PRESCRIBING VITAMINS FOR DENTURE PATIENTS

Why should dentists not prescribe vitamins for elderly denture patients? Pediatricians and physicians regularly prescribe vitamins for babies and children to keep them healthy. Is this supplemental attention not necessary during adolescence and in later life? One occasionally sees an octogenarian who is a "ball of fire," but he is the rare individual who utilizes his dietary intake to the maximum; not all persons are able to accomplish this feat.

The cost of vitamin supplements, although great, is less than the price of a package of cigarettes per day. Vitamins are much less expensive than ill health, hospitalization, loss of job, and failure to adjust and to adequately support the reparative process necessary for successful adaptation to their dental prosthesis.

NUTRITIONAL PREPARATIONS

I use several preparations which contribute to the well-being and support of nutrition of dental patients.

Geriplex.— Geriplex* is a vitamin-mineral formula which aids patients to prepare for their later years. This preparation contains eight vitamins, minerals, and a starch digestant, rutin. The formula was selected and combined in Kapseal form to be used as a supplement to the regular diet of middle-aged and older patients. Its use is helpful in preventive geriatrics. Geriplex also protects against vitamin and mineral deficiencies which are the result of stress. This preparation contains choline, which is a substance essential to the transport and utilization of ingested fat.

Eldec.—Eldec* is a synthetic vitamin-mineral hormone supplement in Kapseal form. Eldec is designed to serve as an effective aid in preventive geriatrics, supplementing the natural sources of essential vitamins, minerals, hormones, digestive

*Parke, Davis & Company, Detroit, Mich.

enzymes, and protein factors. Deficiencies of these substances are a part of the aging process. Supplementation with these essentials aids in the establishment and maintenance of a sense of well-being.

The physiologically balanced combination of estrogen and androgen in Eldec is more desirable in deferring tissue changes resulting from age than is either hormone used alone. Any drug containing gonadal hormones or any hormonal combination is contraindicated in patients with carcinoma of the breast, genital tract, or prostate gland or in those patients with a familial tendency to that type of malignancy. The usual daily dosage is one Kapseal three times per day before meals. Women receiving treatment for 21 days should allow a 7 day rest period before continuing.

Myadec.—Myadec* is a high potency vitamin-mineral formula. It is used in the treatment of chronic fatigue, loss of appetite, irritability such as may be present in adapting to new dentures, and nutritional deficiencies of geriatric patients. Also, Myadec aids presurgical and postsurgical patients by shortening their convalescence after extractions. The contribution of Myadec to patients with conditions that require dietary restrictions, such as obesity, diabetes, peptic ulcer, and nephritis, is of great importance. Such preparations also are indicated for patients whose vitamin-mineral intake may result in deficiencies.

Thera-Combex.—Thera-Combex* combines factors of the B complex with vitamin C in high therapeutic potency and is effective for patients with megaloblastic anemias who require stimulation of adequate hemopoiesis. These patients may exhibit cheilosis and glossitis caused by riboflavin deficiency or metabolic deficiency. Such illnesses as chronic alcoholism, intestinal hypermotility, vomiting of pregnancy, and malabsorption syndromes may account for some of the nutritional deficits which patients suffer.

Neo-Cortef.—Neo-Cortef† is an adrenal steroid preparation which may be administered by the dentist. Edema is often noted in the mucoperiosteum underlying the denture base in many older patients with the nephrotic syndrome. Neo-Cortef may be helpful in such situations. The chronic alcoholic also responds well to ACTH therapy. The dosage and administration of ACTH should be in the hands of a physician who is familiar with the widespread metabolic effects of the drug. ACTH should not be used in tubercular patients or in those suffering from acute thrombophlebitis. Neo-Cortef as an ointment is beneficial when applied to ulcers caused by anemia, which produce a general tenderness of the underlying tissues without obvious impingement of the denture base or localized occlusal stress. Very often, one application of the ointment on the denture will reduce the pain in the conjested tissue.

Mycostatin.—Mycostatin‡ is a dusting powder which may be applied to the tissue surface of dentures to relieve irritated soft tissues. This antibiotic is useful in the treatment of oral moniliasis (thrush) and Spirillum infections.

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*Parke, Davis & Company, Detroit, Mich.
†The Upjohn Company, Kalamazoo, Mich.
‡E. R. Squibb & Sons, New York, N. Y.

NIACIN AND IRON DEFICIENCY

Often, patients complain of burning sensations of the tongue and cheeks and have the feeling of a dry puffy mouth. This is frequently the result of a niacin or an iron deficiency.

MYXEDEMA

The edema which accompanies myxedema is the result of hypothyroidism. In this syndrome, the lips are thickened, the tongue is somewhat enlarged, and the reflexes may be delayed. If the patient is dentulous, the teeth may appear to be separated. In the edentulous person, dentures will not fit as well because of enlarged ridge tissues and associated structures of the lips and tongue. While this is a medical problem, alertness of the dentist may allow early referral of the patient to his physician.

ANGIONEUROTIC EDEMA

Edema of the hands, especially the dorsal surface, is suggestive of angioneurotic edema and may call for simple sedation. The drugs meprobamate and reserpine, or other tranquilizers of the barbiturate class such as pentobarbital or secobarbital sodium, may aid in the reduction of this edema within a few days of administration. I have noted the cessation of the gagging reflex with the administration of meprobamate 3 hours before the dental appointment.

PSYCHOLOGIC PATIENT PREPARATION

In addition to the physiologic preparation of the geriatric patient who is to receive dentures, a psychologic preparation is most important. Sears' book, *New Teeth for Old,*[2] is helpful not only to the dentist but also to the patient who has lost or is about to lose his natural teeth and who requires sound information regarding health problems. Two booklets prepared by the Detroit Dental Clinic Club are helpful: *A Few Tips From Your Dentist Concerning Your New Dentures*[3] is a guide in the use and care of new dentures; *Nutrition for the Denture Patient*[4] aids the patient in the proper preparation and use of foods and other nutritional agents.

BEAUTY AND HEALTH

Beauty is not only skin deep, it is bone deep. Health depends upon the quantity and quality of the food one eats as well as upon proper mastication. The daily exercise of the involved muscular forces is a dominant factor in the preservation of facial contours. The function of swallowing and massaging the neck are extremely important in improving blood circulation of the head, throat, and sinuses. These exercises reduce excess tissue and create and maintain a healthy appearance about the mouth and throat. Healthy tissue is radiant and improves the appearance of either natural or artificial teeth. Daily exercise and care of neck muscles are important, especially to women patients, for when the neck muscles are properly toned,

the skin is taut and smooth with less superfluous tissue and fewer wrinkles. Careful cosmetic attention also improves denture appearance.

A remark by Benjamin[5] is an apt summation of our cause: "There is no cure for old age, only those who die early escape it. But now we can add life to our years, years to our lives," along with the pleasure of constructing dentures for our elderly patients.

SUMMARY

Many denture failures are the result of nutritional deficiencies. Good health and nutrition of older patients are necessary for the successful wearing of dentures. The food patients eat has much to do with their health and recovery from ill health. In order that nutritional deficiencies can be corrected, the diets of older patients must be supplemented with synthetic vitamins and minerals. In this way, the supportive tissues will be properly replenished and the tissue integrity will be maintained. Medical care may be necessary, and psychologic education by means of literature is important to the health and happiness of older patients and to their understanding of their role as denture wearers.

REFERENCES

1. Spies, T. D.: Nutrition and Disease, Postgrad. Med., 1955.
2. Sears, V. H.: New Teeth for Old, ed. 3, St. Louis, 1959, The C. V. Mosby Company.
3. Detroit Dental Clinic Club, Complete Denture Section: A Few Tips From Your Dentist Concerning Your New Dentures, Detroit, 1958.
4. Detroit Dental Clinic Club, Complete Denture Section: Nutrition for the Denture Patient, Detroit, 1957.
5. Benjamin, H.: How to Prolong the Prime of Life, Readers' Digest, June, 1957.

16350 East Warren
Detroit, Mich.

TROUBLE SHOOTING IN COMPLETE DENTURE PROSTHESIS

Part VIII. Interferences With Anatomic Structures*

JOSEPH S. LANDA, D.D.S.
New York, N. Y.

EFFECTIVE AND EFFICIENT TROUBLE SHOOTING does not depend solely upon relieving sore spots, but more so upon the ability of the dentist to determine when and why a denture should be remade. After a certain number of adjustments, a decision to make a new lower denture may save a lot of trouble to the patient and dentist alike.

There are important biomechanic and psychologic reasons why these dentures should not be relined or rebased. First, the patient is psychologically impressed with the dentist's good will in making a new denture, and second, the lower denture may have to be radically changed (denture outline, degree of jaw separation, etc.).

HIGH, KNIFE EDGE SHARP RIDGE

There are two important phases to consider when dealing with the high, knife edge ridge: (1) the relief of the sharp ridge on the cast with tinfoil and (2) a reduction of the degree of jaw separation. In many instances, both of these requirements must be satisfied. The denture, having been relieved on the crest of the ridge, should lean firmly against the tissues on both sides of the ridge. In addition, whenever possible, such a denture should be slightly overextended buccally to derive additional support from contact with the external oblique line (Fig. 1).

The masticatory mucosa of the ridge crest of these patients is situated between a knife edge bony ridge underneath and a rigid denture above. Therefore, the lighter the load that falls upon the lower denture the better. To achieve this, the new lower denture should be built with the shortest possible vertical dimension of occlusion that is compatible with esthetic appearance. In this way, the forces of the masticatory muscles may be reduced to a level more tolerable to the high and sharp ridge. Another way of achieving the same results is to relieve the crest of the ridge in the impression. However, this requires skillful and careful execution and depends upon the impression material used. Plaster of Paris lends itself best for this purpose.

The right way to tackle the difficult ridge problems is to cautiously relieve the sore spots as they arise. Parallel with this are the checking and correction of the occlusion. If the patient still complains after a series of adjustments over approximately 4 weeks, it is time to plan a remake of the lower denture.

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*Part I, J. PROS. DEN. 9:978-987, 1959; Part II, 10:42-46, 1960; Part III, 10:263-269, 1960; Part IV, 10:490-495, 1960; Part V, 10:682-687, 1960; Part VI, 10:887-890, 1960; Part VII, 10:1022-1028, 1960.

The type of soreness observed in high, sharp lower ridges varies with the quality of the denture. However, with the average denture there is widespread soreness over almost the entire occlusal surface of the sharp ridge. The more painful areas are usually grayish in appearance and are definitely established only after a careful digital examination. Severe soreness is manifested by white edematous areas which look bruised or are about to open up. Such soreness must be relieved more generously than the simple grayish irritations. However, caution must be exercised, because "overrelieving" places a double burden on the adjacent tissues. It is always safest to relieve judiciously and not replace the denture for a night or 24 hours. By that time, the edema is reduced so that when the adjusted denture is placed in the mouth it causes no pain.

The situation becomes more complicated if the masticatory mucosa is detached from the periosteum. The movable mucosa rubs against the bone when the lower denture moves in function.

Alveolectomy may be the cause when the mucosa becomes detached from the periosteum. If the objective of the surgical procedure is to remove the bulk of soft tissue that is in the way of the construction of a prosthesis, the operation is often successful. However, reattachment of the mucosa to the periosteum usually does not occur. More often, the area of detachment of the mucosa from the periosteum becomes larger.

THE MUSCLES OF MASTICATION AND EXPRESSION

When making a diagnosis and prognosis for dentures, most of our attention is focused on the *structures* with which we deal. If we engage in a study of function of the individual parts, we can learn only fragmentarily about them. Thus, we examine visually the contraction and relaxation of the pterygomandibular raphe and may reinforce this by a digital examination to determine the intensity of its contraction. We may apply the same exploratory procedures to the masseter, buccinator, mylohyoid, genioglossus, and palatoglossus muscles. All of this will give us only a superficial idea of the structure and positional relationship of the parts involved. It is the ensemble, the collective, creative activity of all the muscles and their mutual interplay that determines, in the final analysis, the function of the masticatory mechanism.

Slight overextension of the denture border is preferred to slight underextension. However, excessive overextension is prejudicial to denture retention. During the examination of the lower denture for overextension, the patient is instructed to protrude the tongue slightly until the tip rests upon the lower lip. By placing the index fingers on the occlusal surfaces of the lower teeth, we can determine if the lower denture remains firmly seated on the denture-supporting structures. The mouth should not be opened wide for this test, just enough to insert the two index fingers.

If the denture is lifted from its position, three possibilities are to be considered: (1) the denture is overextended in the region of the genioglossus muscle, and the contraction of this muscle with the forward movement of the tongue dislodged the denture; (2) the denture is overextended in the bicuspid-molar region and is dis-

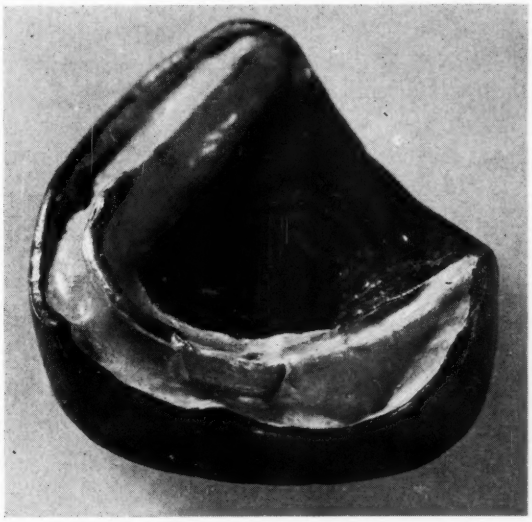


Fig. 1.—A high and extremely sharp lower ridge requires special treatment during the construction of dentures. The sharp crest of the residual ridge is relieved with tinfoil (28 or 21 gauge depending upon the degree of sharpness). Posterior teeth with a very narrow buccolingual diameter are used, and the vertical dimension of occlusion should not be excessive. If anything, a slight overclosure is preferable.

lodged by contraction of the mylohyoid muscle; and (3) the extreme distolingual border of the lower denture is overextended, and the denture is dislodged by the forward movement of the retromylohyoid curtain, formed by the palatoglossus muscle medially and the pterygomandibular raphe laterally. In the first instance, the denture is usually lifted anteriorly. In the second instance, the entire denture is lifted from position. In the third instance, the entire denture is dislodged from position and moved forward.

In testing the buccal and labial flanges of the lower dentures for retention, the cheeks and lips are drawn outward until they become almost perpendicular to the ridge. The index finger of the other hand is kept on the occlusal surfaces of the teeth on the same side. If the denture lifts up from its position, the border may be overextended. The buccal and labial flanges of the upper denture are tested in a similar manner, except that the index finger of the opposite hand is held in contact with the denture vault.

There are many other ways of studying denture retention. For instance, while the patient opens his mouth slowly, the dentist observes whether or not the dentures remain in position. The patient is asked also to move the tongue to the right and left corners of the mouth to determine whether he experiences any loosening of the dentures.

All tests for denture efficiency—retention, stability, centric occlusion, phonetics, esthetics, etc.—are more accurate and more reliable when explored carefully during the adjustment period than at any time during the construction of the dentures. This is because it is more convenient to handle a finished denture that is already

functioning in the patient's mouth and because of the valuable information which may be elicited from our patients. The subjective feeling of the patient when *intelligently elicited* is of tremendous help in denture prosthesis, so fascinating, but also deeply permeated with so many invisible and intangible causes for failures.

If the patient is furnished with dentures that are constructed scientifically, but which he cannot wear, our efforts and the patient's money have gone to waste. If, on the other hand, the dentures are constructed without regard to basic scientific principles and, yet, the patient reconciles himself to these restorations, the dentist has sold the patient a commodity instead of a health service. Dentures are successful only if the dentist is satisfied with his work from a biologic and technologic standpoint and the patient is happy with their performance in function.

THE CORONOID PROCESS

As a rule, there is ample space between the maxillary tuberosity and the coronoid process to allow for free movements of the coronoid process with an upper denture in position. Occasionally, however, the maxillary tuberosity descends as a result of missing mandibular posterior teeth over a long time, and/or there is an overgrowth of the tuberosity in a buccal direction.

When an upper denture is constructed over such tuberosities and the flanges are too thick, the coronoid process may meet interference in function. If the interference is severe, it will be easily detected. Either the patient himself will point out the soreness and the nature of the trouble, or else after 24 or 48 hours of wearing the dentures, there will appear redness and tenderness of the tissue involved.

The buccal surface of the denture flange over the tuberosity must be thinned until the discomfort is eliminated. Care should be exercised not to perforate the denture or otherwise mutilate it in that area, because retention is usually lost together with the loss of the buccal flanges. A remake of the denture is then necessary, because attempts at repairing these flanges most frequently terminate in failures.

Mild interference of the buccal flange of the upper denture with the movements of the coronoid process is much more difficult to detect and may be more troublesome. The irritation of the buccal mucosa is not sufficient to aid in detection, and the rather vague complaints of discomfort of the patient often misdirect the dentist's efforts.

A study of the anatomy and morphology of the coronoid process does not suggest any momentous relationship between this osseous structure and the function of complete dentures. However, if we consider the complex function of the various fibers of the powerful temporal muscle that is attached to the coronoid process, we get a different perspective of its significance.

WHARTON'S (SUBMAXILLARY) DUCT

Wharton's duct in a static state may be far enough from the lower lingual denture border so as not to warrant the existence of interference. Yet, there are instances in which the insertion of a lower denture causes complete or partial closure of Wharton's duct.

Clinically, the closure is manifested by the enlargement of the submaxillary gland to a point that the patient gets frightened, mistaking this condition for a sudden and serious abscess. Actually, the gland usually returns to normal soon after the denture is removed from the mouth. In instances in which the compression of this duct is slight or of short duration with long intervals, or when no contact whatever is effected between the denture border and the duct, the diagnosis of this condition becomes more difficult. Some patients complain that the gland becomes swollen slightly when they eat. With others, it occurs only when they drink fruit juices. When asked to call at the office immediately upon occurrence of the swelling, they invariably state that it is of too short duration. Experimentation with some patients with fruit juice drinks in the dental office failed to evoke the same reaction. In severe instances of compression of the lumen of the duct by the denture border, judicious relief brings immediate relief.

In all mild duct closures, the treatment is symptomatic. In many instances, this mild discomfort disappears by itself during the period of adjustment to the dentures. In other instances, a reduction of the thickness of the lingual flange, without disturbing the border, affords the patient the desired relief. Therefore, it may be assumed that while Wharton's duct in a static state is rather far away from the border of the lower denture, there are exceptions to the rule. Second, it may be assumed also that when the muscles of the floor of the mouth and the adjacent structures are functioning actively, Wharton's duct or its innervation occasionally contacts with the denture border. This, in turn, may cause reflex symptoms. We must exercise great care not to mutilate the lower denture by excessively reducing its borders.

136 East 54th St.
New York 22, N. Y.

REMOVABLE PARTIAL DENTURES

IMPRESSION TECHNIQUE FOR REMOVABLE PARTIAL DENTURES

HAROLD M. KRAMER, D.M.D.
Portland, Ore.

MOST DISTAL EXTENSION removable partial dentures are constructed from single reversible or irreversible hydrocolloid impressions. An accurate reproduction is made of the teeth, and the soft tissue surfaces are recorded in a passive or negative state. Border molding is impossible because of the use of overextended stock trays. Occlusal rests are included in the finished denture, and when masticatory forces are applied, the restoration becomes a lever with the rests as a fulcrum. The denture base achieves functional tissue adaptation only at the terminal or retromolar pad region. This denture fits correctly on the cast but fits the tissues in the mouth only at rest position.

PATHOLOGIC LEVERAGE

Pathologic conditions resulting from leverage can be loose teeth, tissue atrophy, occlusal imbalance, general irritation to the mucosa, and a sense of frustration on the part of the patient. Some steps which can be taken for correction of damaging leverage are:

1. Recording the ridges in modeling compound before placing hydrocolloid in the stock tray. The mucosa is sometimes recorded in its functional position and related to the clasped teeth in this condition.

2. Use of various stress breakers. Stress breakers are used routinely by some dentists on all lower distal extension partial dentures. Stress breakers definitely improve any technique that does not allow for proper and uniformly functional displacement of the ridge tissues. However, the stress breaker denies the vertical support afforded by the rigid clasp or attachment. Thus, all or most of the functional vertical stress is placed on the residual ridges. An exception to the usual stress breaker partial denture is the dowel rest attachment. This restoration provides stress breaking without appreciable loss of vertical and lateral support.

3. Relining of denture bases under closing stress immediately or soon after completion. This technique has many adherents. However, many times the mucosa is recorded in a displaced position and is in adaptation with the denture base only when under applied stress.

Read before the Pacific Coast Society of Prosthodontists at Palo Alto, Calif.

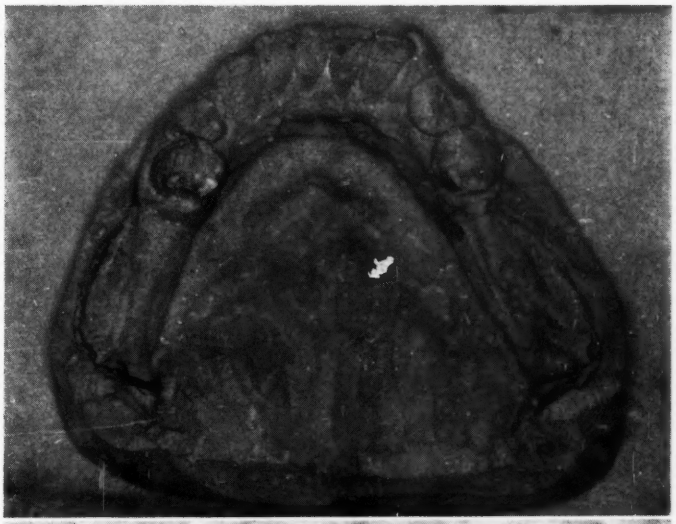


Fig. 1

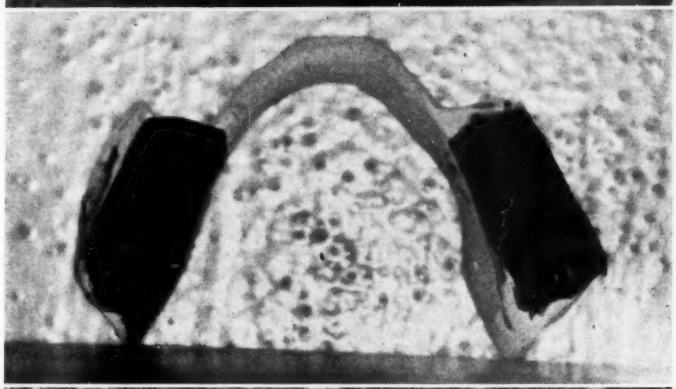


Fig. 2

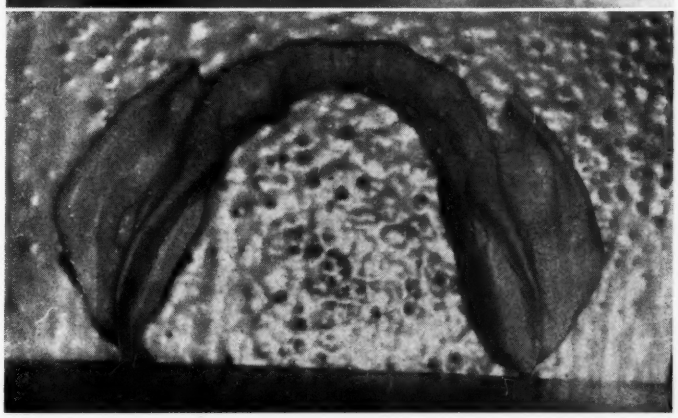


Fig. 3

Fig. 1.—A cast is made after the crowns are made and fitted. The outline for the tray is made on this cast. Note that the tray covers only the soft tissue areas of the ridges and the area of the lingual bar.

Fig. 2.—The tray is made to fit the ridge surface without a spacer and wax occlusion rims are added to the tray.

Fig. 3.—A zinc oxide and eugenol impression is made in the tray.

SINGLE IMPRESSION TECHNIQUE

Some internal precision attachment distal extension partial dentures are constructed from one hydrocolloid impression. Assuming that accuracy can be maintained through crown construction, placing of attachments, soldering, and other steps, it is impossible to record the ridge mucosa in functional balance to the abutments with these impressions.

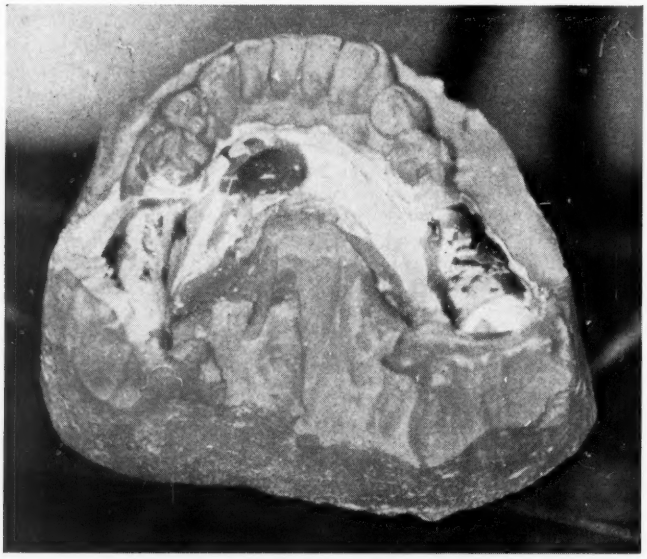


Fig. 4.—A cast is made in a two piece impression. The soft tissue impression has not been removed from the cast.

FUNCTIONAL TECHNIQUE

The technique to be described is based partly upon the procedure and principles of Hindels.[1] The lower distal attachment removable partial denture is constructed with the denture bases in functional relation to the attachments.

Study Casts.—Mounted study casts are used for diagnosis and survey. Areas to be "boxed" for reception of attachments are cut on the cast by use of a surveying instrument. Therefore, a "blueprint" is available before the tooth preparations are made.

Crown Construction.—The tooth preparations are made. Full or three-quarter crowns are always used. The three-quarter crown is used if the tooth is of sufficient length and the buccal or lingual surface is free from caries. If the buccal surface is damaged and the lingual surface is free from caries, a reverse three-quarter or a three-quarter crown with a porcelain or plastic veneer can be used.

A complete lower reversible hydrocolloid impression is made with regard for tooth preparations but not for full ridge detail, and the crowns are constructed. Boxing space for internal attachments is surveyed and cut into the wax patterns. The cast crowns are placed on the teeth in the mouth, and the occlusion is adjusted.

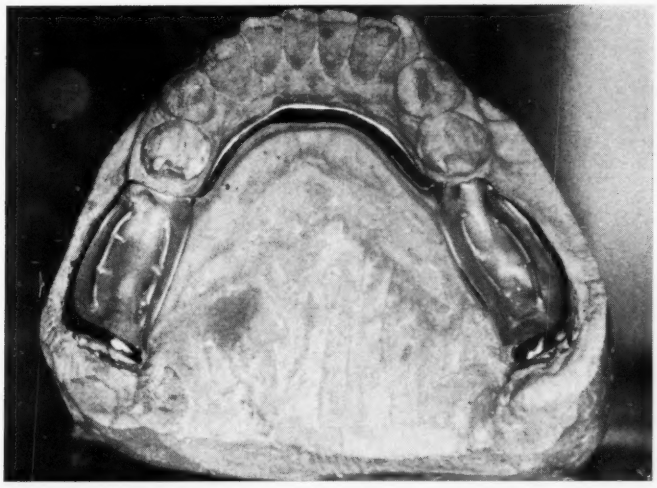


Fig. 5.—A metal casting is made to fit the soft tissue surfaces.

Tray Construction.—A complete mouth alginate (irreversible hydrocolloid) impression is made in a stock tray, and a self-curing resin tray covers the ridge and the lingual bar region is made on the resultant cast (Fig. 1). The tray is made of a self-curing plastic that is adapted by hand. It is trimmed short of the contemplated borders of the finished denture. No spacers are used over the ridges on the cast, but the tray may be slightly and selectively relieved (Fig. 2). The lingual flange of the tray should extend from just short of the lingual gingivae of the anterior and bicuspid teeth to a position just short of the floor of the mouth when the tongue is extended. Wax occlusion rims are built on the occlusal surface of the tray in the edentulous areas. The sides of the rims are undercut (Fig. 2).

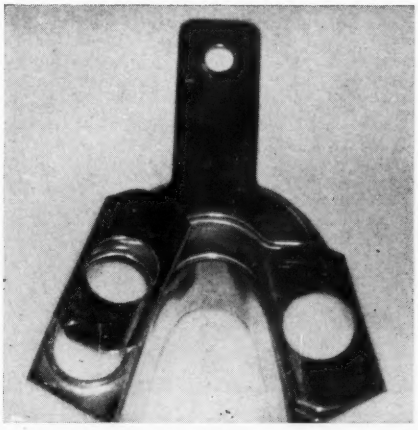


Fig. 6.—A tray with finger holes for placing pressure on the metal casting while the over-all impression is made.

Fig. 7

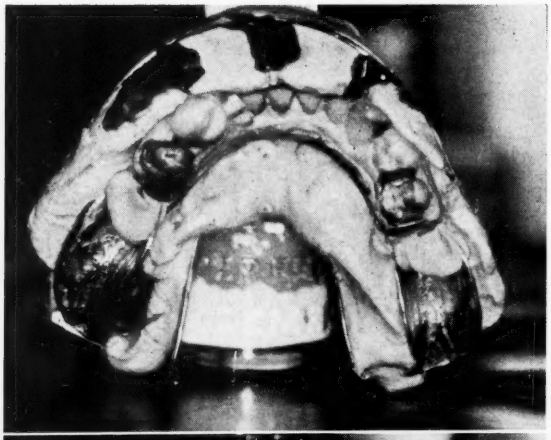


Fig. 8

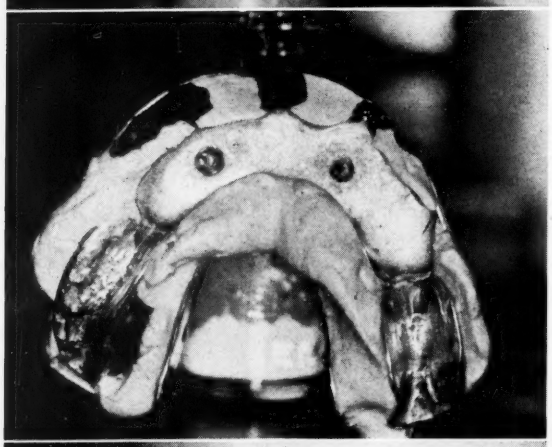


Fig. 9

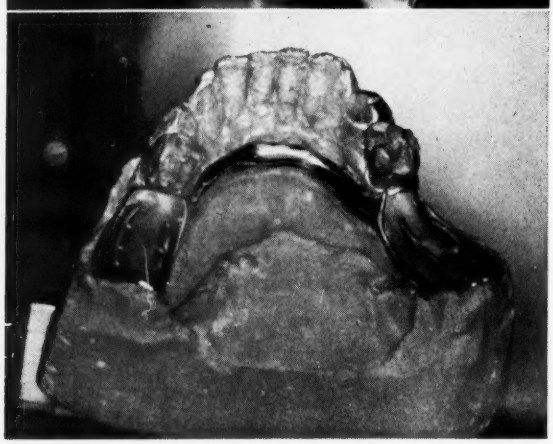


Fig. 7.—The master impression prepared for cast pouring.
Fig. 8.—Low-fusing metal is poured into the impressions of the remaining teeth and crowns.
Fig. 9.—The master cast.

Tissue Impression.—A passive impression is made in the acrylic resin tray with zinc oxide and eugenol impression material (Fig. 3). A very slight pressure is exerted on the wax rims until the paste is partly set. Then, the borders of the impression are molded gently.

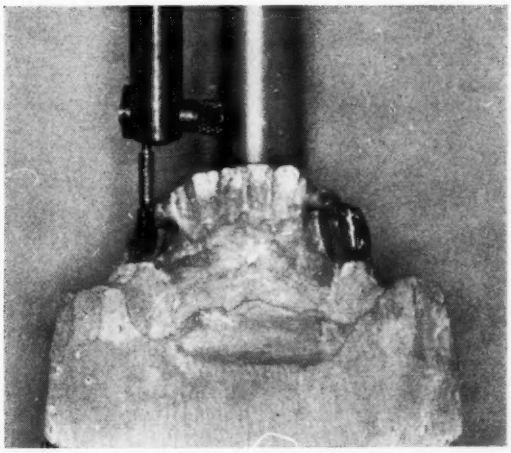


Fig. 10.—The female parts of the attachments are placed in the crowns.

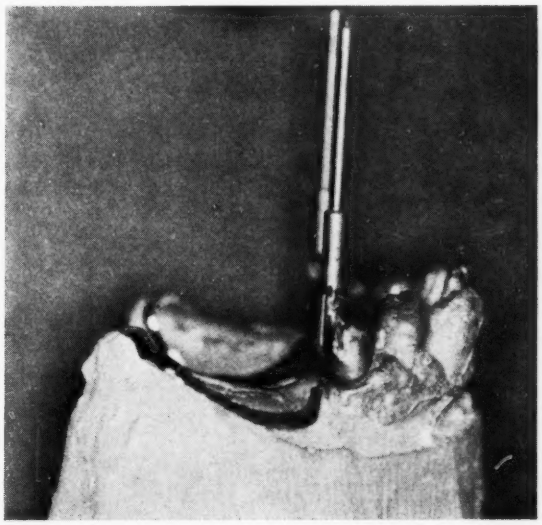


Fig. 11.—The parallelism of the male parts of the attachments is checked on a surveyer.

Impression of the Teeth.—The impression is removed and examined for pressure areas. If present, these areas are relieved, and a second zinc oxide and eugenol impression is made over the first one. The satisfactory impression is carefully trimmed to remove any excess material around the teeth and replaced in the mouth.

A complete lower alginate (irreversible hydrocolloid) impression over the plastic tray and impression is made in a stock tray. Because of the undercuts in the sides of the wax rims, the impression of the soft tissues will become a part of the two piece impression. An artificial stone cast is made in this impression (Fig. 4). The plastic tray material will not soften in hot water, and if forced, it may fracture the cast. The tray is cut with a bur at the median line on the lingual side and separated one side at a time.

Fig. 12

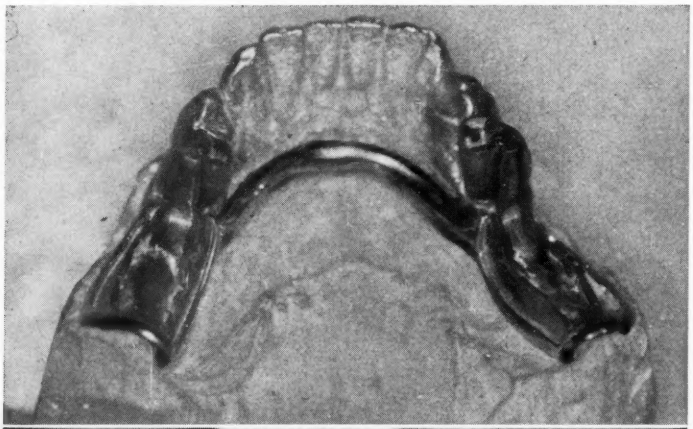


Fig. 13

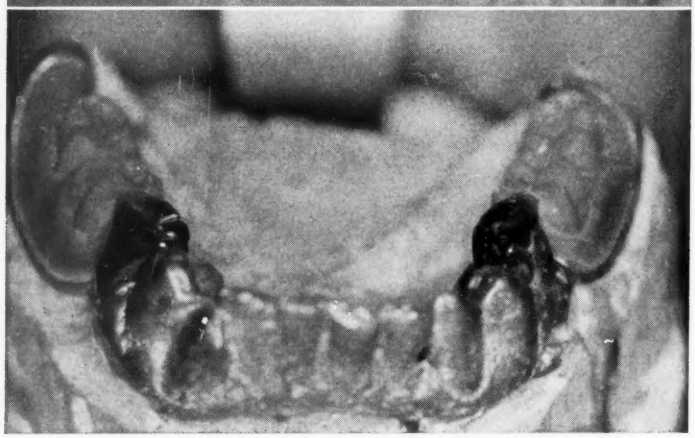


Fig. 12.—The attachments are soldered to the metal base.
Fig. 13.—The teeth are added to the base.

Metal Base Construction.—The cast is duplicated in a refractory material, and a gold or chrome metal base is constructed (Fig. 5). Connectors from the base to the abutments are *not* included in the casting. Wax rims with undercuts on their buccal and lingual sides are built on the metal base, and the base is placed in the mouth. The crowns are placed on the teeth. A tray with finger holes over the edentulous areas (Fig. 6) is selected.* It is loaded with impression plaster and

*Hindels, Coe Laboratories, Inc., Chicago, Ill.

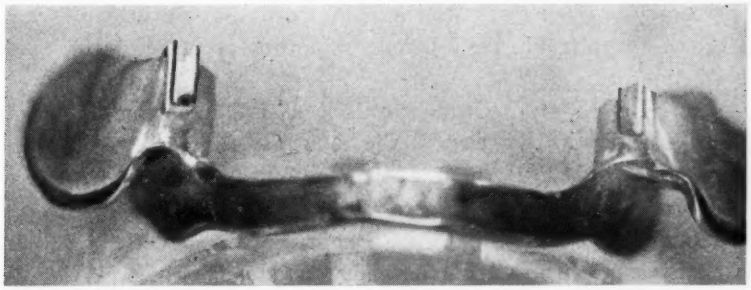


Fig. 14.—The completed denture.

placed in position in the mouth over the metal base and occlusion rims. The index fingers are placed through the openings in the tray, and *positive but not excessive* pressure is applied to the base through the wax occlusion rims.

The impression is removed in such a way that it retains and removes the crowns and the cast base as a unit. A part of the sprue may be left on each of the crowns to facilitate their removal within the impression. Modeling clay is used to block out a part of the interior of the crowns and the metal base (Fig. 7). Low-fusing (about 135° F.) metal* is poured into the crowns and the anterior section of the plaster impression (Fig. 8). Retention pins are placed in the low-fusing metal, and the balance of the impression is poured in artificial stone. The resultant master cast is as accurate as can be achieved with available materials and methods (Fig. 9).

Internal Attachments.—The "jackets" (or female attachments) for the internal attachments are fitted and soldered to the crowns. The jackets are kept within the contour of the abutment teeth (Fig. 10). The male parts of the attachments are placed in their seats in the crowns and tested for parallelism (Fig. 11). The assembly is duplicated, and the connectors from the base to the attachments are waxed, cast

*Precious Metals Research Works, New York, N. Y.

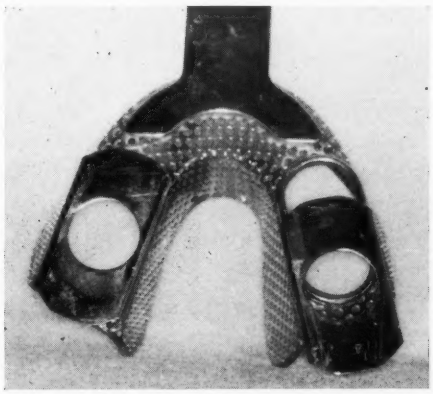


Fig. 15.—A tray for reversible hydrocolloid impression material with finger holes for applying pressure to a soft tissue tray underneath.

in gold, and soldered to the base and to the male parts of the attachments (Fig. 12). It is not necessary to place strip inserts in the bottom of the attachment boxes (the female parts of the attachments) before soldering because of the nature of the impression technique.

The excess length of the attachments (extending beyond the tooth) is not removed until the denture is tried in the mouth. Occlusal registrations are made and the denture teeth are set in wax and attached to the metal base with acrylic resin (Fig. 13).

The resultant denture will be in its proper functional relation to the abutments when the male parts of the attachments are completely seated. When the occlusal stress is released, the denture base will return to its rest position on the ridge, and the attachments will rise very slightly from their seated positions (Fig. 14). Occlusion is maintained in function, and the intermittent stimulation to the mucosa affords physiologic health to the supporting tissues.

Resin Denture Base.—If acrylic resin denture bases are preferred to the metal base, the plastic tray passive impression is substituted for the metal base when the plaster impression is made. However, *the resin cannot be cured on the master cast* because of the presence of the low-fusing metal.

CLASP REMOVABLE PARTIAL DENTURE

The clasp denture is constructed according to the technique described by Hindels.[1] The passive impression is made in a plastic tray and an over-all irreversible hydrocolloid impression is made in a "Hindels type" alginate tray using pressure on the wax rims through the holes over the edentulous areas (Fig. 15).

SUMMARY

An impression technique for an internal attachment removable partial denture has been described. The procedure allows the denture base to fit the mucosa in the resting state and the denture to be in proper relation to the abutment teeth during function.

REFERENCE

1. Hindels, G. W.: Load Distribution in Extension Saddle Partial Dentures, J. Pros. Den. **2**:92-100, 1952.

414 Medical Arts Bldg.
Portland, Ore.

CROWN CONSTRUCTION FOR BROKEN DOWN PARTIAL DENTURE ABUTMENTS

R. H. KILLEBREW, D.D.S.
Des Moines, Iowa

A SINGLE GOLD OR VENEERED CROWN can be made to fit a badly broken down tooth and at the same time to fit a clasp of an existing removable partial denture. By this means, the period of usefulness of the tooth as an abutment and of the partial denture can be extended.

TECHNIQUE

The correct contour of the tooth is first restored with red utility wax. Then the removable partial denture is placed in position, and the patient is instructed to close the mouth gently into centric occlusion. This makes an impression of the occlusal rest in the utility wax. Then, the denture is carefully removed from the mouth.

A perforated half arch tray is filled with an alginate (irreversible hydrocolloid) impression material and placed over the tooth to be restored. The patient is instructed to close the teeth against the tray and to hold it with gentle occlusal pressure until the impression material has set thoroughly. The impression is removed in a vertical direction and kept damp until the preparation of the tooth for the crown has been completed. Then, the impression is dried with air and all projections of the impression into the interproximal spaces are removed *except those adjacent to the prepared tooth.* Thus, the impression can be reseated accurately on the teeth without interference. The prepared tooth is thoroughly dried with air, and a thin coating of utility wax is melted over the preparation.

A small amount of cold-curing acrylic resin is mixed and placed in the half arch impression of the tooth being restored. The half arch impression is then reseated on the teeth, and the patient is instructed to close the mouth just hard enough to hold the tray in place. (The patient can hold the impression much better than the dentist.) After the acrylic resin has set, the half arch alginate (irreversible hydrocolloid) impression is removed, and the acrylic resin crown is left in place on the prepared tooth. This crown is a replica of the original tooth.

The resin crown with its lining of utility wax is removed from the preparation. The soft coating of the utility wax inside the crown makes this possible. The wax and any excess resin are removed from the crown.

Since acrylic resin shrinks, the inside of the resin crown is not an accurate record of the shape of the prepared tooth. So, the crown is reamed out with a round bur and then filled with inlay wax. When sufficient wax is in the crown, the wax is heated with a hot spatula until it is molten. The crown is placed in position

on the prepared tooth and the patient is instructed to close the teeth into occlusion. If the tooth is an abutment for a removable partial denture, the denture is placed in the mouth before the wax inside the acrylic resin shell has hardened. This will ensure good relationships with the clasps and occlusal rest. Cold water is applied to the crown on the tooth until the wax is cold. Then the excess wax is removed with a warm spatula. If an acrylic resin veneer is to be used, the window is cut while the pattern is on the prepared tooth in the mouth.

The resin crown with its wax core is removed, and a large sprue is attached to it with sticky wax. Extra wax is added on the contact areas to compensate for polishing. Then the resin and wax crown pattern is invested and cast.

712 A. Equitable Bldg.
Des Moines, Iowa

FIXED PARTIAL DENTURES

THE ROLE OF TORQUE, TORSION, AND BENDING IN PROSTHODONTIC FAILURES

EDWIN S. SMYD, D.D.S.
Detroit, Mich.

TORQUE IS FORCE acting through a moment arm or lever which produces rotation about a given point or axis. Torque deforms or stresses the body on which it acts. The deformation may be compressive, tensile, a combination of these two, or torsional. A nail driven under the impact of a hammer is an example of a body placed in compressive stress as a result of the torque in the hammer. When a nail is drawn by the claw of the hammer, tension takes place in the nail, while the stresses in the claw of the hammer itself are compressive and tensile combined. The last instance is identical to that occurring when a cantilever bridge is subjected to a concentrated load on the cantilever. If a body is twisted through application of torque, the resulting deformation is torsion. Torsion or angular deformation produces the kind of stresses that occur in the drive shaft of an automobile, in the helix or torsion bar of a car's suspension, in teeth and partial dentures subjected to eccentric loading, and in most extractions of teeth.

Torque and torsion are the commonest physical manifestations of living. Movement of any part of the body invokes torque. The movement of the mandible with its parts against the maxillary dentition is not only a specific type of torque operating in bodily function, but at each of the points where this torque is brought to bear, secondary torques develop often with torsion of the contacting members. Through mandibular action, torque figures prominently not only in the maintenance of health in the structures involved but also in the wearing out and failure of the moving or resisting parts.[1-5]

GENERAL CONSIDERATIONS

The serviceability of the teeth may be ended by accident, intent (surgery), incident (restorative dentistry), or biochemicophysical sequence (disease, aging). A fine line divides physiology and pathology. What is tolerated by tissues as normal response to stress during health and youth may be traumatic in later life. This is

Read before the Midwinter Meeting of the Chicago Dental Society.

true for organic response throughout the body economy, so it should come as no surprise when evidences of it occur in the dental picture. We must expect deteriorative change with aging even if the mechanics of dental fabrications are properly compensated. However, what is of utmost significance is the *rate* at which deterioration proceeds. Dentists have the power of not only minimizing the deteriorative process in teeth and the supporting structures but even reversing the trend. The limits are set by the physics of the teeth and their supporting structures and the chemistry of intercellular and intracellular activity.

Disease and aging are reflected in altered cellular chemistry. Unless loading of the physical system decreases with aging, degenerative changes can only be accelerated. The teeth and supporting structures of middle-aged and elderly persons are not doing well in their own right in most instances. At this time, the dentist

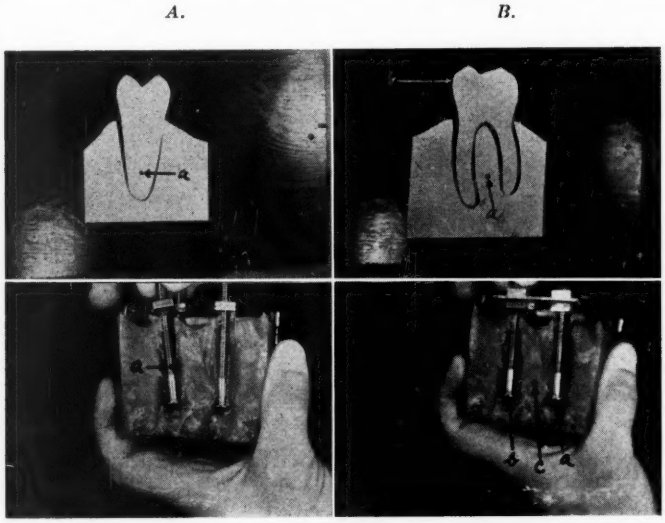


Fig. 1.—*A*, A single-rooted tooth rotates to transverse force on the center *a* in the apical third of the root of the tooth. *B*, The lower molar rotates to transverse force *b* about a center *a* in the radicular bone. Translation of the roots occurs. *C*, The "single-rooted" laboratory specimen rotates to transverse force on a center as illustrated in *A*. *D*, The double-rooted laboratory specimen rotates on a center at *c* just as the lower molar did in *B* when transverse force was applied.

must extract hopelessly involved teeth and place leverage on the remaining ones. This is a vicious circle and one with which dentists must grapple in restoring the dentitions of these patients.

Torque produces prosthodontic failures either through failure of the foundation (the abutment teeth become loose and therefore useless) or failure at the abutments. Except for poorly designed partial dentures, failure at the abutments seldom means a rupture of the framework. When the prosthesis is cemented, sometimes the framework or the abutment casting will be bent. However, more frequently the abutment tooth will be broken or the abutment casting will be *loose* from the tooth.

Torque which is excessive for the normal or physiologic response of the investing structures causes failure of the foundation. This is analogous in metallurgy

to subjecting materials to loads beyond their elastic range. Leverage plays a critical role in intensifying or relieving the load on teeth and their supporting structures.

Loads or stresses which are greater than the restorative materials or teeth can withstand elastically cause failure of the abutments. Fixation of the abutments produces leverage which enhances the strength of the foundation, but at the same time, the fixation raises the stresses in the abutments.

FOUNDATIONAL CAPACITY

While the periodontal membrane has been studied and mathematically analyzed from the point of view that it is an incompressible membrane, dentists know that this is not the clinical picture of patients presenting themselves for partial dentures. Usually, the abutment teeth have perceptible mobility even in the absence of "pockets." The mere lengthening of the clinical crown, caused by physiologic resorption of the alveolar crest, is attended by some loosening of the tooth. When

Fig. 2.—Each tooth distal to another tooth in the dental arch is *lateral* as well as distal.

periodontoclasia supervenes, the loosening may be serious enough to preclude use of the tooth in a restorative procedure.

Single-rooted teeth describe rotational movements when subjected to lateral forces, and an axis of rotation is established somewhere near the apical third of the root of the tooth (Fig. 1, *A*). Displacement of the membrane occurs on the side toward which the tooth is moved, and tension of the periodontium takes place along the opposite side of the tooth from the axis of rotation occlusalward. The conditions are reversed below the axis of rotation.

Multirooted teeth also turn on axes in the apical third of the roots, but if the transverse force is directed across the roots (Fig. 1, *B*), one root moves down under the force and the root nearer the point of application of the force moves up. Rotation occurs about a point in the bone septum between the two roots.

Models made to simulate dental conditions revealed that rotation of teeth in their sockets is not a property peculiar to teeth. If a solid object embedded in a yielding milieu is moved to and fro, the object will describe a rotational movement with an axis of rotation at some distance from the end of the object (Fig. 1, *C*). The laboratory specimen also rotated on an axis between the two "roots" when it

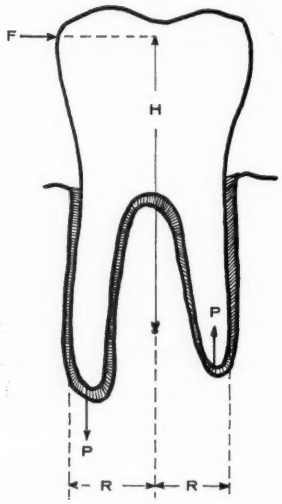


Fig. 3.—The torque of the applied force *F* is resisted by the torque of the couple in the investing structures. At equilibruim, $FH = P \cdot 2R$.

was so designed and subjected to transverse or horizontal forces (Fig. 1, *D*). The conversion from a single-rooted to a multirooted structure seemed to suggest the difference in behavior between a post and a cube. If it be imagined that the multirooted tooth is a cube having the dimensions enclosed by its roots and that it is embedded in periodontium and bone, the center of rotation would occur at the same vertical level as for a single-rooted tooth and would pass through the center of the cube. By extension of this reasoning, the broader the cube the more stable it becomes because of the increased radii resisting rotation. This is another way of saying that leverages are acting to give the broader cube greater stability.[4,5]

Each tooth distal to another tooth in the dental arch is both distal and *lateral* to its neighbor. This may be seen by observing the teeth in relation to the median sagittal plane (Fig. 2). Whenever two single-rooted approximating teeth are joined, the new unit will gain the stability of the larger radius of rotation. To buccal, lingual, mesial, or distal transverse force, the new unit will turn on an axis of rotation between the roots just as if it were a cube of the dimensions set by its radii of rotation.

The farther apart the roots happen to be in the assembled unit, the greater the orbit of rotation and the more stable the unit becomes. The stability gained is a matter of mechanical advantage or leverage.[1,3] However, more is gained than just mechanical advantage. The periodontium is subjected to *purer* tension as well as *decreased stress* (Fig. 3).

From Fig. 3, it is apparant that torque FH is resisted by countertorque $P \cdot 2R$. At equilibrium $FH = P \cdot 2R$, or $\frac{FH}{2R} = P$. When FH is unity, $\frac{1}{2R} = P$.

Periodontium and bone take tensile stress well. Osteoclasia occurs where compression is sustained by the tooth and its investing structures. Osteogenesis takes

place on the tension side. In the resolution of restorative problems, we should maximize tensile stress and minimize compressive stress in the investing structures of the teeth.

Leverages through the bone are readily tolerated by Nature. The upper dentition comprises roughly an outer half circle of teeth which interdigitates and overlaps the lower teeth, an inner half circle. Transverse or horizontal loading occurs in the vertical component of mastication through the compression of food between the inclined cusps of the upper and lower posterior teeth. Transverse components of force during this phase of mastication push the lower teeth into tighter contact, for they comprise the inner arch. Interproximal contact buttresses the lower teeth, but the reactionary components push the upper teeth apart. Interproximal contact does not buttress the upper teeth in this instance. No significant histologic difference exists between the teeth and investing structures of the two jaws to compensate for the more drastic loading of the upper teeth except leverage. Only the upper posterior teeth possess lingual roots. The mechanics of the situation does not require lingual roots on the lower teeth. Nature uses and accepts leverage of this kind in her architecture.

Whether the tension of the periodontium is produced by upward or downward translation of the roots apparently makes no difference, for an upper molar tooth may be rotated both ways: buccally in working occlusion, lingually in balancing occlusion. The key to successful intervention in weakened dentitions is to use levers and torques within the bone to counteract torques by levers outside the bone which dentists must employ through prostheses.

Mastication consists of crushing or vertical forces and milling or translatory forces. The latter are anteroposterior transverse forces; the former are applied against inclined surfaces and, therefore, have buccolingual transverse components of force. The investing structures gain mechanical advantage in both anteroposterior and buccolingual dimensions when fixation of the abutments is employed. Furthermore, since the transverse axis of mandibular rotation is not on a plane common to the occlusal surfaces of the teeth but considerably above it, even "vertical biting forces" in centric occlusion contain components of force which act to thrust both the mandibular and the maxillary teeth forward.[5] *Even in pure centric occlusion, all teeth take a degree of horizontal loading, and the foundation gains mechanical advantage when the abutment teeth are united by fixation.*

Mandibular forces exerted through the leverage of prosthetic restorations multiply the torques on abutment teeth. Torsion of individual teeth occurs frequently in mastication and is responsible for the failure of porcelain jacket crowns and other individual restorations. However, torsion is much more significant when its effects are increased through leverage. The fixed partial denture between an upper cuspid and the first molar is a good example. Assume that the patient is biting into a crust of bread that is very resistant to mastication and that the crust is compressed against the occlusal surface of the first bicuspid pontic and lingual incline of the cuspid abutment. Three things occur: (1) the cuspid is depressed more deeply in its socket than the molar because the load is concentrated over the cuspid, (2) bending of the fixed partial denture occurs in the region of the bicuspid, and (3) the

cuspid is moved laterally. The molar resists the lateral displacement so there is both bending and twisting of the metal framework. The same thing occurs in all posterior fixed partial dentures during eccentric mastication (Fig. 4).

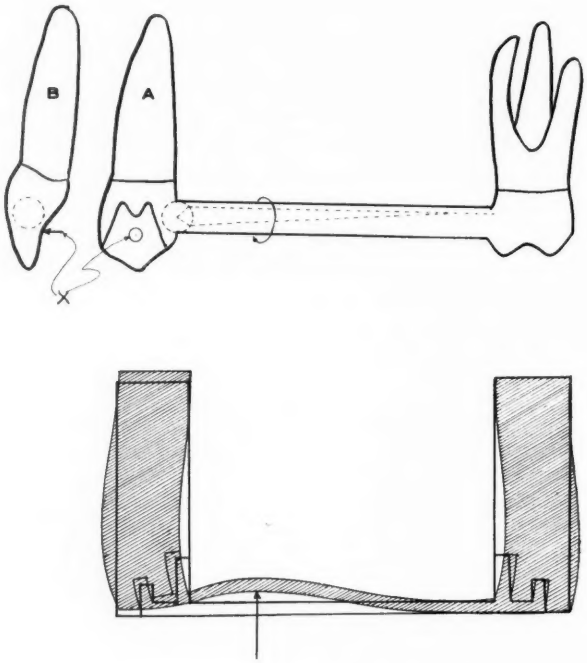


Fig. 4.—When concentrated loading occurs on the fixed partial denture in the cuspid–first bicuspid region, both bending and torsion occur simultaneously. *B* is a side view of *A*. Transverse force is applied at *X*.

An even worse situation exists if the crust of bread is engaged on the incisal edge of the cuspid and the patient puts traction on the sandwich to tear off the morsel of food. The occlusion is heavy and close across the upper cuspid. Since the cuspid is cone shaped, little stock in the tooth structure is afforded for cavity preparation. This combination of circumstances evolves rather thin abutment castings for cuspids. Pinledge and three-quarter crowns are examples. However, the thinness of the lingual envelope is a liability, for such thin castings are very flexible. Bending may occur across the lingual plate of the cuspid three-quarter crown, and the distal half of the abutment casting may peel away and loosen from the cement bond (Fig. 5).

The bending and twisting of the framework when the foundation is rigid puts heavy strain on the abutment castings and the cement which holds them.

THE MECHANICS OF DENTAL STRUCTURES

The kinematics of dental restorations requires that all materials which go into the construction, that is, gold alloys or other alloys, porcelain, plastic, dental cement, and tooth structure, be used only at loads which these materials can sustain elas-

tically. The most critical element in this composite is dental cement. It is of primary concern that the physics of dental cement be correlated with the physics of the other structures.

Dental cement can take great stress in compression, 6,000 to 12,000 pounds p.s.i. according to the National Bureau of Dental Standards. The kinematics of fixed partial dentures sometimes stresses only small areas of the dental bond. Pressures rise alarmingly when small areas bear all the stress of the load. As an example, it is conceivable that as little as 1/16 of a square inch of some inlay or abutment may take all of an instantaneous load: $\left(\frac{1}{16}\right)^2 = \frac{1}{256}$ sq. in. And $\frac{6{,}000}{256} = 23$ pounds is the maximum load which the weaker specimen could take. Engineering practice requires that a large margin of safety (safety factor) be applied in all constructions. This challenges the adequacy of our service. However, since dental cements have virtually no flow, it is quite unlikely that dental cement will ever fail in the thin sections used for luting dental restorations if the stresses brought to bear are compressive.

The security of the bond may be questioned if the bond is subjected to shear or diagonal tension. Dental cement acts as a bond not through adhesion but rather as a keying mechanism between the irregularity and roughness of the inlay on the one side and the irregularity and roughness of the tooth on the other. Values for the strength of dental cement in shear and diagonal tension may be ascertained. However, these values have only relative significance, for what we really wish to know is the significance of these qualities as manifested in the given number of keys stressed at a given time.

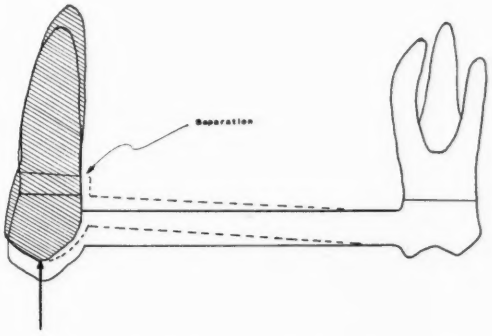


Fig. 5.—Simultaneous axial and labial forces applied to the cuspid are resisted by the molar abutment. The framework bends across the thin lingual plate of the cuspid pinledge or three-quarter crown, and separation of the abutment casting from the abutment tooth occurs.

Brittle materials like dental cement and structural cement or concrete are weak in tension and shear as compared with their strength in compression.[2,4] Undoubtedly, many prosthetic abutments subject the cement bond to the extremes of its physical properties.

The strength of the cement bond is determined by the following factors: (1) the strength of the cement in compression, tension, and shear, (2) the number and size of the interlocking keys, (3) the areas of the bond between opposing walls, (4) the taper of the cavity preparation, (5) the tolerance or closeness of fit between the casting and the tooth, and (6) coupling.

The most important of these factors controlled by the dentist is coupling. The deficiency of the cement bond in shear and diagonal tension may be made up by some form of male-female engagement or coupling. Either internal engagement with a pin or dowel or extension of the dovetail into a groove in the buccal or lingual tooth structure (the casting furnishes the male and the tooth structure the female part of the coupling) or external engagement (the crown is the female and the tooth structure the male component) is used. Since dislodging forces acting on an abutment casting are not usually coaxial with the draft of the prepared tooth,

Fig. 6

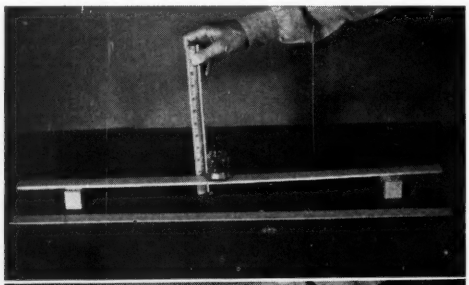


Fig. 7

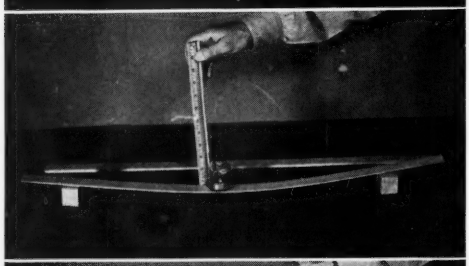


Fig. 8

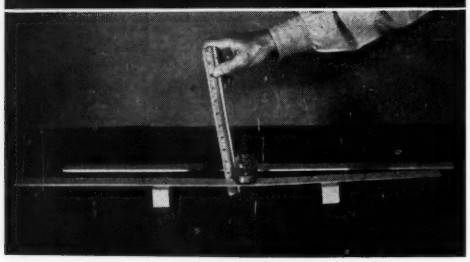


Fig. 6.—Bending occurs when a load is applied to the ¼ inch slat. The molecules above the central plane are in compressive stress, while those below are in tensile stress. The supports are 2 feet apart.

Fig. 7.—The ⅛ inch slat bends *8 times* as much as the ¼ inch slat when the same load is applied. The supports are 2 feet apart.

Fig. 8.—Both slats bend *8 times* as much at 2 feet as they do when the supports are placed 1 foot apart.

mechanical coupling between the metal of the casting and the tooth may be employed to resist torque. Cement under the mechanically coupled parts is thus in compressive stress, the best possible way to load dental cement.

KINEMATICS OF FIXED PARTIAL DENTURES

The kinematics of fixed partial dentures may be used to illustrate the torque and bending which abutments must endure and the bending, torque, and torsion of the framework. The fixed partial denture is a beam between two abutments. A plank across a creek, a footbridge, a vehicular bridge, or the horizontal supports of a floor are all examples of beams. All beams have certain kinematic characteristics and mathematical truths in common. Since fixed partial dentures are forms of beams, the following statements may be made.

The simplest beam is a plank or slat freely supported at its ends or abutments. Figs. 6 and 7 show two slats cut off the same piece of lumber. The only difference between them is that one is twice as thick as the other. When the slats are freely supported on the blocks, the slats will bend when a weight is placed upon either one.

Engineers refer to the "fiber" of the slat as being composed of layers of molecules. The layers above the middle layer are squeezed together or compressed by the bending of the slat. Those layers below the middle layer are tensed or pulled apart. The middle layer is neither compressed nor tensed, and engineers refer to this layer as the neutral axis. The compression or tension of the layers of molecules is not uniform but becomes greater as points are taken farther and farther away from the neutral axis. So the compressive stress is greatest in the outermost layer of molecules above the neutral axis, and the tensile stress is greatest in the outermost layer below the neutral axis. Whenever a beam fails these are the molecules that rupture first. The compressed part of the beam is shorter and the tensed part longer when the beam is stressed.

MATHEMATICAL RELATIONSHIPS

If a thin slat is placed on supports and loaded with the same weight as a thick slat, the slat one-half as thick will bend *8 times* as much as the thicker one. Further, if the supports are moved from 1 foot to 2 feet and each slat is again loaded, both slats will bend *8 times* as much as they did before (Fig. 8). Thus, the amount of bending varies inversely with the cube of the depth, $\left(\frac{1}{\frac{1}{2}}\right)^3 = 8$, and directly with the cube of the length, $2^3 = 8$.

The significance of these findings is that where stiffness is needed in dental fabrications, as much depth of metal should be used as possible. In order to restrict excessive excursion of the pontic, we need as much metal from the occlusal to the gingival surface as the circumstances warrant. To accept less makes the pontic springy, which bends and twists the abutment castings excessively. Especially is

this true in long sections. A two tooth fixed partial denture bends 8 times as much as a one tooth span, and a three tooth span, 27 times as much. The great advantage (cubed function) in stiffening a section is gained only through increasing the depth or decreasing the length. *Doubling the width* of the section only makes it *twice* as stiff.

Deflection is a function of moment of inertia and for rectangular sections is expressed through the formula $\frac{bd^3}{12}$, where b is the width of section and d is the depth. Round sections are expressed by the formula $\frac{\pi d^4}{64}$, where d is the diameter. When the kinematics of square beams is considered irrespective of length, $b = d$ and varies directly with d, so the formula $\frac{bd^3}{12}$ may be written $\frac{d^4}{12}$. The deflection of square beams varies inversely with the *fourth* power of the depth. From the formula $\frac{\pi d^4}{64}$, this is also true of round sections.

Since abutment castings share in the bending of the pontic, the great danger of failure in dental restorations lies in thin sections of abutment castings. Pinledge or three-quarter crowns on cuspids are most likely to be deficient.

The order of values holds for all materials whose moduli in compression and tension are approximately equal, so it includes all springy materials. The only difference to be observed in the kinematics of materials other than wood is that the higher the modulus of a given material, the stiffer the material will be to bending. The same order of values applies to the abutment castings as to the pontic itself, because the proximal flange and the isthmus and dovetail combined comprise levers in their own right. Bending of a restrained beam (pontic fixed at one or both abutments) puts bending into the restraining abutment or abutments (Fig. 9).

APPLICATION OF SPECIFICS TO PRACTICE

When the abutments are firm and much tooth structure remains in the abutments, fixed partial dentures are usually not much of a problem. Stress breakers may be employed between abutments, and should be employed, if the teeth are firm in their sockets but the remaining crown of either of the abutment teeth is greatly weakened. Under no circumstances should deep preparations be made in the abutment teeth to obtain rigid abutment castings when rigidity and strength may be gained by surface reduction. The secondary abutment may be a simple individual tooth restoration, but the lug which it receives must be free so that the primary abutment may function independently of the secondary. If little tolerance occurs in the lug, the secondary abutment casting will come loose. When it is desired to limit movement at the secondary abutment, as with a precision lug, the secondary abutment is prepared with as much retention as possible. The severity of loading at the secondary abutment will then approximate that at the primary abutment.

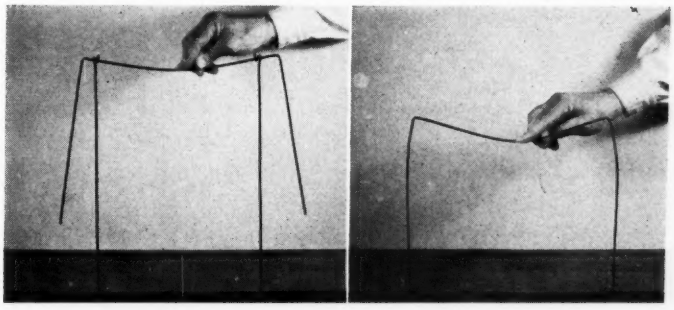
When teeth have been loosened by disease, all measures should be taken to treat the disease including the equilibration of the occlusion. Equilibration of the

occlusion should be done for mechanical as well as therapeutic reasons.[4] Investing structures which have been damaged by periodontal disease may be restored to normal function by treatment of the disease, hygiene, and physiotherapy combined with the proper application of leverages in the mechanical treatment of the restorative problem.

Fixation of abutments is indicated in periodontal problems to thwart failure of the foundation by torque. Equally important to mechanical adequacy, restorative work must ensure hygienic adequacy. Ridge laps should be narrowed, interproximal embrasures opened, the patient instructed in the use of interdental stimulators, and a blunt needle furnished to thread dental floss under the pontics.

Undoubtedly, the fixed partial denture provides the most stable foundation to vertical and horizontal loading and stresses the periodontium most favorably through tension. A fixed partial denture from cuspid to cuspid and to the first molar of either or both sides is stable to buccolingual and mesiodistal forces because the abutments are widely separated and such a structure has long radii of rotation. Frequently, several posterior teeth of either or both sides are missing but all anterior teeth remain. If the health of the investing structures or mechanics precludes unilateral fixed partial denture construction, the precision attachment removable partial denture is the next best choice.

Teeth which are periodontal risks should not be used at less than their maximal capacity to take tensile stress. Clasps with occlusal lugs use teeth at their lowest potential for load resistance. Internally retained precision attachments or clasps with long, well-integrated cast lugs fitting into inlays especially prepared for such lugs are second choice to fixed partial dentures. Such restorations apply the load nearer the axis of rotation of each abutment tooth in its socket, thereby improving the mechanical advantage of the tooth and lessening the torque applied on the investing structures. Bodily engagement of abutment teeth also changes the center of rotation from within its socket to a center between the supports when transverse forces of mastication occur. Thus, mechanical advantage is gained by the abutment teeth.



A. *B.*

Fig. 9.—*A*, When the beam of the U-shaped wire is supported and loaded, no stress occurs in the vertical ends. *B*, When the vertical ends are restrained from movement, bending of the beam introduces bending in the vertical ends or "columns" and they bow outwards. The abutments of fixed partial dentures share in the kinematics of the pontic.

Removable partial dentures of simple clasp retention and occlusal lugs have undesirable features. Removable partial dentures are really "bridges." When the denture is supported between abutments, it is like a freely supported beam. If the denture has support over an edentulous ridge without a terminal abutment, it is a "pontoon" bridge. Clasps on teeth must be placed just below the greatest circumference for retention but other parts of the clasps are occlusal to the greatest circumferences. The teeth can turn under the clasps. Since this type of partial denture preserves the individual tooth rotations, no mechanical advantage is gained through the use of multiple abutments. It is as if the bridge were a simple beam supported on sections no sturdier than the occlusal lugs. The eccentric bearing of the lugs on the marginal ridges of the abutment teeth causes the teeth to tip on their axes of rotation even in vertical loading. The occlusal lugs are usually round and of thin section, which makes them flexible. If the lug is thin and on an inclined surface, it will bend under vertical loading and the parts of the clasp arms which bear occlusally from the greatest circumference of the tooth force the tooth laterally. This is most apparent when cuspid teeth are clasped. Every effort should be made to prevent or reduce lateral displacement of abutment teeth. The lugs bend and shear off from the excessive loading, making subsequent use of the denture even more damaging.

A removable partial denture with abutments at the upper first bicuspid and second molar of one side and a distal extension bearing on the first bicuspid on the other side is similar to a "pontoon" bridge. The framework should be rigid across the palate, since it is desirable to resist the vertical displacement of the pontoon by transferring as much of the torque to the molar of the opposite side as possible. This is best achieved by using a double bar. The anterior bar is usually at a lower level and presents a different axis than the posterior bar. This has the effect of spreading the metal over a wide band between the upper and lower limits and makes the palatal bars stiff with the least amount of metal. If a single bar is used, advantage should be taken of the downward anterior slope of the palate to stiffen the bar.

Stiffness in palatal and lingual bars is also highly desirable to gain stability against the horizontal forces of occlusion. Stiffness is a function of the cube of the *depth* of section.

Where avoidable, teeth should not be subjected to mechanical disadvantage, particularly when the teeth are periodontally weakened. Fixed partial dentures should be used to unite isolated teeth to the adjacent teeth, and one or more precision attachments should be used within the fixed entity to support a removable partial denture.

Multirooted teeth are often lost in later life through periodontoclasia. When heroic measures are employed to save such teeth by resection of the detached gingivae, caries may develop in the bifurcation or trifurcation of the roots. Hemisection may be employed, but often the teeth must be sacrificed. Single-rooted teeth may be retained with greater success than the molars by gum resection, osteoplasty, and adjunctive periodontal treatment. When united into multiples by fixed partial dentures, such teeth may be used to give service for extended periods of time. Forethought should be employed in order that removable or fixed partial dentures are

constructed so the main part of appliance may be salvaged and redesigned if abutment teeth are lost.

When many teeth of one jaw are opposed by few teeth in the other jaw, external levers should be reduced by omitting the second molars on the denture of the handicapped jaw. When this is done, the denture base should remain as extensive as circumstances permit. When compromises must be made, mechanics should favor the lower teeth. The upper dentition can always be restored with greater facility than the lower, even in complete dentures.

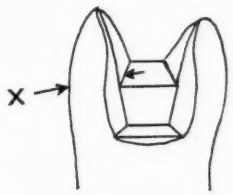


Fig. 10.—The tooth structure is weakened by an internally retained abutment. If the remaining cusp *(X)* interposed between the arrows is further reduced in stock by a cement base, its strength and deflection will vary with the square and the cube, respectively, of the remaining tooth structure.

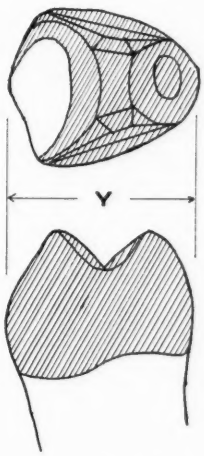


Fig. 11.—Externally retained abutments restore the full buccolingual *(Y)* and mesiodistal strength of the tooth structure.

Large restorative undertakings entail postoperative risks. Calcific degeneration of the pulp takes place spontaneously with aging. Many times it is difficult to attribute pulp stones to external stimuli. Dental caries and the chemical and physical aspects of operative dentistry are known to be pulpal irritants which produce inflammatory reactions in the pulp and advance the degenerative process. In later life when more extensive operative dental procedures must be performed under the circumstances of lowered pulpal and somatic vigor, pulpal degeneration with necrosis occurs.

TABLE I. ELECTROMOTIVE SERIES OF THE METALS

Lithium
Rubidium
Potassium
Barium
Strontium
Calcium
Sodium
Magnesium
Beryllium
Aluminum
Manganese
Zinc
Chromium
Iron
Cadmium
Cobalt
Nickel
Tin
Lead
HYDROGEN
(Antimony
(Arsenic
(Bismuth
Copper
Mercury (ous)
Silver
Palladium
Mercury (ic)
Platinum
Gold

Teeth with extensive restorations that require root canal therapy are weakened abutments. They are reduced in structure because of the root canal curettage, are brittle, and may subsequently fracture. Dowels should be placed in root canals to gain retention and to reinforce the tooth structure.

The increased foundational support gained by fixation of abutments places greater stress on the cement bond. The cement bond is the weakest link in the system. As the foundation becomes stable and rigid, the abutments are wracked more severely by the kinematics of the structure they support. Thus, smaller abutments may be used with stress-broken fixed partial dentures because the foundation yields more readily. Unless cavity preparation is intelligently carried out to withstand the more drastic wracking which goes with fixation, failure of the cement bond and the restoration is likely.

CAVITY PREPARATION

Abutment castings that support a prosthetic lever through either fixation or precision attachment must be rigid and retentive through coupling. Abutment

castings share in the kinematics of the structures they support. If the abutment casting is too thin, it will lack sufficient strength to grip the abutment tooth firmly during the kinematics of the prosthesis. If the casting bends or twists away from the abutment tooth, substrate will enter. The danger of using thin pinledge and three-quarter crowns on anterior teeth attached to levers has been discussed. Reduction of depth of section or gauge of retaining pins is attended by a loss of rigidity in the order of the third and fourth powers, respectively. Furthermore, three-quarter crowns on anterior teeth are cut across three surfaces rather than four as in posterior teeth. The three-quarter crown on an anterior tooth is more nearly like an MOD inlay on a posterior tooth. The latter is known to be less satisfactory as an abutment than the three-quarter crown.[2,4]

Rigidity may be gained by deep cavity preparation. However, rigidity may be obtained by surface reduction of the abutment tooth better because the shallower preparation preserves the health of the dental pulp.

The dowel and the crown provide the most effective coupling between the abutment casting and the tooth. Both the dowel and the crown present a continuously opposing surface to the tooth. When prepared with little taper, both provide mechanical coupling. Crowns have the additional advantage of large area for cement bond. Tough metals like partial denture gold alloys take stress in tension well so a crown is a rigid structure even though its walls may be thin.

Multiple abutments for fixed prosthesis frequently have diverse vertical axes, yet all must be prepared to afford approximately the same path of insertion. The crown preparation is most likely to afford sufficient retention with minimal sacrifice of tooth structure. The exception is the three-quarter crown on posterior teeth.

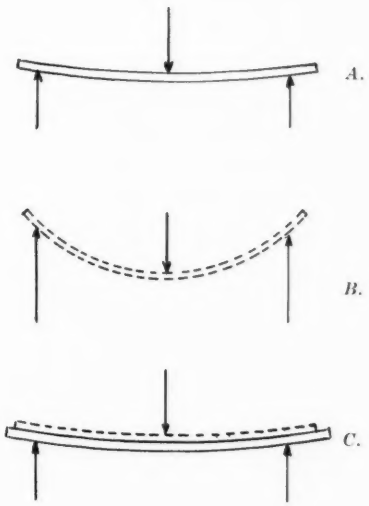


Fig. 12.—Schematics demonstate the strengthening influence of a material with high moduli of elasticity. *A*, "Stiff" material like steel or B gold alloy will deflect little to a given load, *B*, Tooth structure with low moduli of elasticity will deflect greatly to the same load. *C*, The deflection of a composite of tooth structure and B alloy will deflect about as much as the B alloy itself. Most of the stress is borne by the metal.

Since extensive restorative dental procedures usually are for older people, the abutment teeth will usually already have many fillings. All amalgam and other filling material should be removed to assure freedom from caries and to prevent galvanic action between the gold alloy of the abutment and the amalgam.

Dental amalgam contains tin and zinc, which are widely separated from gold in the electromotive series of metals (Table I). Galvanic action releases hydrogen, which in its nascent state is an acid-forming ion: The ion acts on the cement to loosen the abutment, corrodes the amalgam, and promotes recurrent caries where the tooth is exposed.

Internally retained abutments do not serve as well as those that are externally retained. The isthmus of the cavity preparation reduces the depth of the section between both remaining cusps. Direct lateral forces upon the cusps and torques from the restoration that the inlay supports must be resisted by the remaining tooth structure of the cusp. If only a third of the original mass of the cusp remains (Fig. 10), the cusp will only be one-ninth as strong after the preparation, because the *strength* of a section varies with the *square* of its *depth.* The deflection to load varies inversely with the *cube* of the depth and will be even more drastically affected.

The B gold alloys have a modulus of elasticity of 13,000,000 p.s.i. Tooth structure has a modulus of approximately 2,000,000 p.s.i., the dentine being a little less and the enamel a little more. The B golds are much stiffer and will deform less to a given load than tooth structure. If the B gold is used to encircle all or most of the crown (Fig. 11), most of the stresses occurring in the prosthesis which it supports will be taken by the metal of the abutment, and the full buccolingual mass of tooth structure will be restored to function.

That the major deflection and stresses will be borne by the metal of the abutment may be demonstrated by a simple illustration (Fig. 12). First, a wooden slat whose modulus of elasticity is 1,500,000 p.s.i. (close to that of dentine) is placed on supports. The deflection to a given weight is measured. When a second slat or bar of metal, steel, partial denture gold alloy, or other material having a high modulus of elasticity of like dimensions is placed on the same supports and stressed to the same weight, the steel will deflect one-twentieth as much as the wooden slat, partial denture gold one-tenth, and other materials in proportion to their moduli. If the wooden slat is placed upon the steel slat and the weight applied again, there will be little difference in the deflection of this composite as compared with the steel alone because the steel is so much stiffer.

SUMMARY

The effects of torque, torsion, and bending on teeth and the supporting structures were analyzed. The physical properties of dental materials and structures determine the success or failure of dental restorations. All dental structures and materials must be used within their proportional limits of elasticity. Unless the principles of mechanics acceptable to engineering practice are observed in applying and resisting loads on dental fabrications, failure of the foundation is likely. The kinematics of dental restorations determines cavity preparation. Important principles of cavity preparation stem from this study. Unless advantage is taken of this knowledge, failure of the abutments is likely.

I wish to acknowledge the assistance of Mr. Fred Best, structural engineer, and thank him for the many hours of discussion in preparing the engineering aspects of this paper.

REFERENCES

1. Smyd, E. S.: Dental Engineering as Applied to Inlay and Bridge Fabrication, J. Tennessee D. A. **31**:123-129, 1951.
2. Smyd, E. S.: Mechanics of Dental Structures: A Guide to Teaching Dental Engineering at Undergraduate Level, J. Pros. Den. **2**:668-692, 1952.
3. Smyd, E. S.: Principles of Foundational Capacity of Dental Investing Tissues, J. D. Res. **31**:498-499, 1952.
4. Smyd, E. S.: Dentistry Is Biophysics, D. Digest **61**:482-490, 517, 535-544, 1955.
5. Smyd, E. S.: Role of Mechanical Stress in Dentistry, New York J. Den. **28**:277-235, 1958.

Jennings Memorial Hospital
7815 East Jefferson Ave.
Detroit 14, Mich.

ESTHETIC SPLINTING OF MOBILE PERIODONTALLY INVOLVED TEETH BY VERTICAL PINNING

GRANT E. OVERBY, D.D.S.*
University of Washington, School of Dentistry, Seattle, Wash.

PERIODONTAL THERAPY includes procedures to stabilize teeth made mobile by periodontal disease. Many of the available procedures are time consuming, complicated, and expensive and are not acceptable to the dentist or patient. Many teeth are sacrificed because a simple technique for periodontal splinting which would result in an esthetic appearance is not available.

This article presents a method of splinting which involves a lingual or occlusal bar with attached parallel, vertical pins which hold the entire assembly to the teeth. The pins fit into precision tubes which are first cemented into the teeth. The bar can be made to hold facings and can also be used to join pre-existing fixed partial dentures.

PREPARATORY TESTS

At the outset of this study, several anterior teeth were sectioned, and the thickness of dentine at the cingulum was measured. An ample thickness of dentine was found at the cingulum for placement of a sleeve whose diameter was equivalent to that of a No. 558 bur. Such a device could safely be placed to a depth of 2.5 mm. in the lower anterior teeth and 3.5 mm. in the upper anterior teeth.

Accordingly, a pin and sleeve were designed for lingual placement in the cingulum of the anterior tooth (Fig. 1). The tolerance of fit of this pin and sleeve is close and greatly assists retention when the splint is cemented. Parallelism is provided by the taper of the internal portion of the sleeve, the corresponding taper of the No. 700 pin, and the parallel alignment of the several sleeves to the long axis of each tooth included in the splint. Minor discrepancies in parallelism are compensated for by the mobility of the teeth to be splinted. An extracoronal lingual bar associated with these inserts was designed with sufficient rigidity to prevent individual tooth movement once the assembly was in place.

ARMAMENTARIUM

The materials necessary for vertical pinning are (1) gold sleeves with the diameter of a No. 558 bur and knurled on the outer surface for cement retention, (2) gold and plastic pins with the diameter of a No. 700 bur and designed to

*Clinical Assistant, Department of Periodontics and Endodontics.

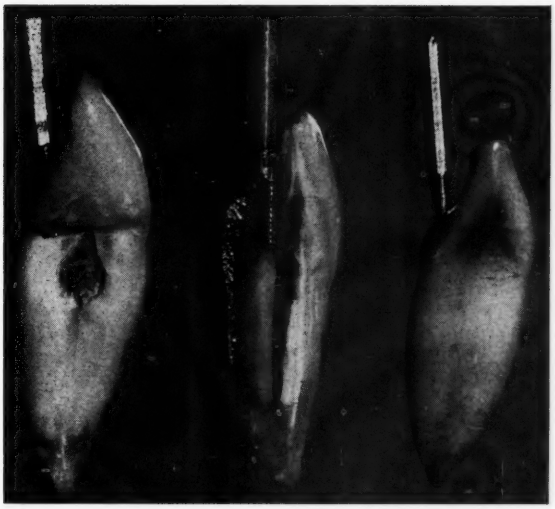


Fig. 1.—Sectioned teeth illustrating the placement of the gold sleeve, with plastic or gold pins attached.

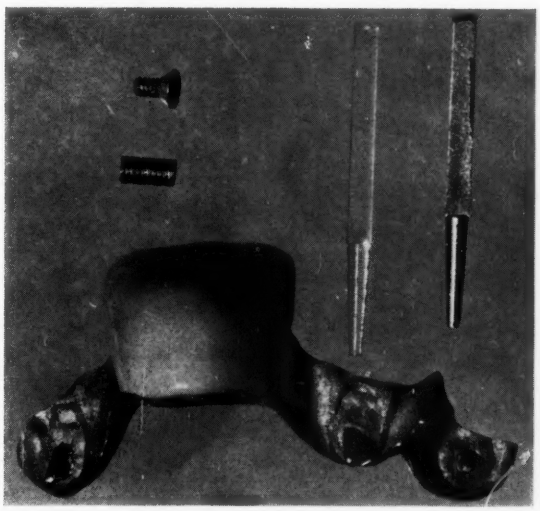


Fig. 2.—The armamentarium consisting of gold and plastic pins, a knurled sleeve, a screw, and a completed temporary three tooth splint with a replacement tooth.

precisely fit the internal portions of the sleeves,* (3) a screw for anchorage of the lingual bar if desired (this screw must be made of stainless steel or plated with either rhodium or gold) (Fig. 2), (4) hydrocolloid or rubber-base impression material, (5) crown and bridge cement, and (6) No. 1 and No. 558 contra-angle burs.

*Pin and sleeve set available from the Wilkinson Co., P. O. Box 303, Santa Monica, Calif.

PROCEDURE FOR SPLINTING LOWER INCISOR TEETH

A starting pinhole is prepared with a No. 1 round bur in the cingulum of each tooth to be included in the splint. This pinhole is widened to the size of a No. 558 bur and extended with this same bur to a depth of 2.5 mm. to accommodate the sleeve. The excavation must be confined to the lingual portion of the cingulum of the tooth and kept parallel to the long axis of the tooth. There will usually be ample space for placement of this sleeve in the cingulum, particularly in view of the pulp recession so often noted in periodontally involved teeth.

After the tooth preparation is completed, the sleeve is cemented to the tooth with crown and bridge cement (Fig. 3). The plastic pin should be within the sleeve at this time to limit the flow of cement. Then, the pin is removed and the sleeve is finished to the tooth (Fig. 4).

Fig. 3

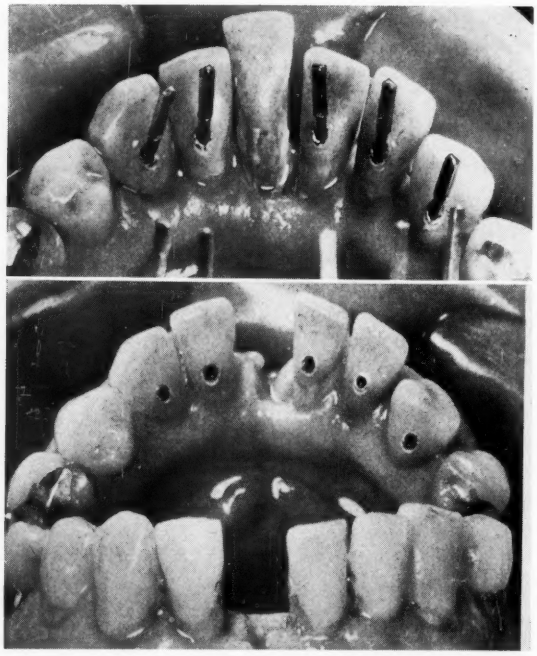


Fig. 4

Fig. 3.—The sleeves are cemented in place and the plastic pins are inserted for the impression.

Fig. 4.—A hopelessly involved tooth is removed prior to placement of a splint.

The gold pin is placed in the sleeve and an irreversible hydrocolloid or rubber-base impression is made. The cast is poured in a refractory investment material and the lingual bar is both waxed and cast directly to the refractory investment cast. An alternative method is to pour a stone cast and work indirectly.

If one does not wish to cast the gold bar to the gold pins, an alternative procedure may be used. The plastic pins are reinserted into the sleeves before the impression is made and then included in the wax-up. The pins will burn out with

Fig. 5

Fig. 6

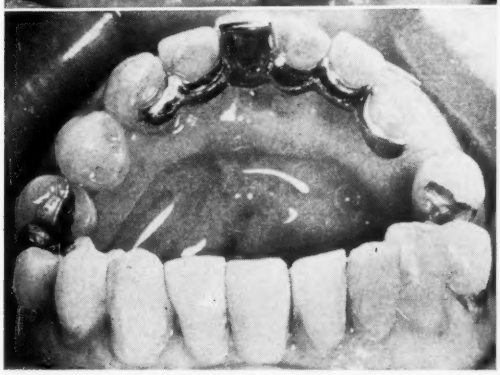


Fig. 5.—The splint is cemented into place, and the excess cement is removed before the facing is attached to it.

Fig. 6.—An esthetic anterior splint which replaces one tooth. If added retention is required, the use of threaded sleeves and screws will attach the bar. This latter method will also facilitate the removal of the splint by the dentist.

the wax, and the lingual bar and pins are thus cast in one piece. Regardless of the procedure used, a preformed wax lingual bar is luted to the pins and adapted into the embrasures, with care used to avoid undercuts. If a tooth is to be added to the splint, a backing for the facing is luted to the wax-up (Fig. 5).

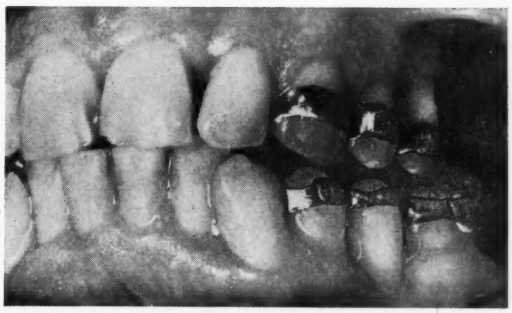


Fig. 7.—Unesthetic temporary band splints are in place on periodontally involved posterior teeth.

Fig. 8

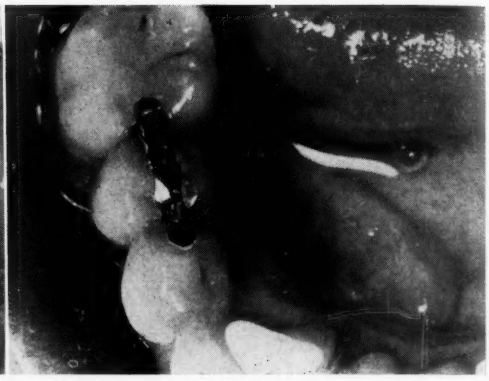


Fig. 9

Fig. 8.—Sleeves are placed in the posterior quadrant of teeth in a shallow channel in the occlusal surfaces to accommodate a gold bar.
Fig. 9.—A posterior splint cemented in place.

When the casting is complete, the lingual bar is polished and the whole splint is tried in the mouth (Fig. 6). Retention of the splint is obtained by the cementation of the pins to the sleeves.

PROCEDURE FOR SPLINTING UPPER INCISOR TEETH

The steps for splinting the upper incisor teeth are exactly the same, except that the excavation is made to a depth of 3.5 mm. Correspondingly, a 3.5 mm. pin and sleeve assembly is used.

PROCEDURE FOR SPLINTING POSTERIOR TEETH

The procedure for splinting posterior teeth is also similar, except that a shallow occlusal channel is prepared so the opposing teeth may clear the bar

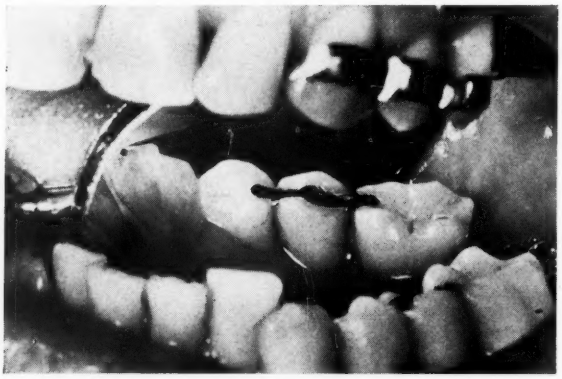


Fig. 10.—Lingual views of splints illustrating the bands on the upper teeth and the pin and sleeve bar on the lower teeth.

connecting the sleeves. This channel, approximately 1 mm. in depth, is prepared before the excavations for the pins and sleeves. A 3.5 mm. assembly is usually employed. The esthetic and practical advantages of this procedure are excellent (Figs. 7 to 11).

DISCUSSION

The possibility of pulp involvement is only an occasional limitation in the vertical pinning procedure. In instances when a 2.5 or 3.5 mm. excavation might result in pulp exposure, a more shallow preparation should be made. Then, the excess in sleeve length is reduced and the gold margin is finished to the tooth in the customary manner.

Retention and caries development are the two major problems associated with this type of splinting. Vertical pinning is contraindicated in the caries susceptible mouth for obvious reasons. The occlusion must be adjusted carefully before and after splint construction. Otherwise, deflective occlusal contacts on tooth surfaces adjacent to the pinning may lead to a loosening of the pins. This loosening in turn produces mobility of the splint, with the likelihood of carious involvement. It has not been possible to determine the effect of the close proximity of the pin to the pulp over a long interval.

Fig. 11.—Esthetic value of the splint is shown after periodontal surgical correction has been completed.

Problems related to retention have arisen and have led to the suggestion that this device be made into a removable restoration with retentive clasps. However, there is no question that more can be accomplished by a fixed splint than by a removable one. An ideal situation would exist if the splint could be removed from time to time by the dentist.*

Vertical pinning has its place as a method of stabilizing mobile teeth. It is adaptable to treatment of periodontal disease which requires splinting. It offers conservation of tooth structure and there is no irritation of the marginal gingivae

*A threaded sleeve is now available which will allow the dentist to attach the bar entirely by screws. This will help in retention and will make the splinting of an entire arch possible.

such as might be seen with full coverage crowns. Vertical pinning has been tested for a 2 year period. The degree of patient comfort is gratifying.

SUMMARY

A method of splinting teeth by use of a bar and several pin and tube assemblies of a special design has been described. This method provides a simple and conservative means of esthetically stabilizing teeth loosened by periodontal disease which otherwise might be lost.

This is a preliminary report, and continued efforts should improve and perfect these techniques.

School of Dentistry
University of Washington
Seattle 5, Wash.

A CONSERVATIVE APPROACH TO ORAL REHABILITATION

JEROME M. SCHWEITZER, D.D.S.*
New York University, College of Dentistry, New York, N. Y.

A DICTIONARY DEFINITION of "conservative" reads: "within safe bounds, moderate, adhering to sound principles, believed to involve little risk." The noun "conservatism," is defined as "the disposition and tendency to preserve what is established."[1]

Oral rehabilitation by means of complete occlusal reconstruction is a difficult and arduous task. Dentists have always engaged in this procedure, but until 25 years ago, it was undertaken by a select few. Dentists approached their objective with timidity and diffidence. Now dentists everywhere are completely reconstructing mouths.

Oral reconstruction has its effect both upon the dentist and the patient. It is time consuming, tiresome, and expensive for the patient, and for the dentist it is exhausting and time consuming. Its goal is the preservation of the dental organ as a functional apparatus. This includes mastication, speech, and esthetic appearance. For the treatment to be completely successful, the reconstruction must not merely halt the destructive forces, but it must enable the organ to perpetuate itself without wearing out in spite of function and aging. For partial success, the forces of destruction must be halted so that continued breakdown ceases.

CONFLICTING THEORIES

Many theories have been advanced as to the cause of occlusal breakdown, but dentists still disagree about the actual causes. There are those who believe in the dominance of the condyles over the teeth and those who believe that the teeth are the controlling factor. Some regard incisal guidance as the most important control, while others make the incisal guidance secondary in importance to the posterior cusp inclines and condylar guidance. In some patients the mandible is moved forward; in others it is retruded. Some dentists believe in the registration of hinge axes, and others scoff at the making of an ordinary face-bow record. Some believe that people chew primarily on the horizontal plane, while others maintain that they chew primarily vertically on or close to the midsagittal plane. There are those who believe that a balancing contact is often traumatic and are willing to eliminate it in their finished restorations; others contend that maximum contact in all positions is essential. Some believe that the shape of the cusps should be parabolic, whereas their opponents are quite willing to accept

Read before the American Academy of Crown and Bridge Prosthodontics, Chicago, Ill.
*Clinical Professor.

flat or even concave cusp surfaces. Some start their mandibular movements from a retruded hinge closure position, and many others will start mandibular movement only from a slightly advanced centric relation position.

THE BENNETT MOVEMENT

One school of thought believes the Bennett movement occurs solely on the horizontal plane, whereas some of their colleagues maintain that it occurs in the sagittal plane. Of course, many of these differences are due to lexicographic variations, but others are more fundamental. Each inventor of an articulator either maintains silence relative to his inventor colleague or asserts that most other machines (except his own) lack the ability to reproduce mandibular movements.

ORAL RECONSTRUCTION AS A SERIOUS UNDERTAKING

When a patient seeks oral repair, be sure complete rehabilitation is needed before engaging in that perilous procedure. If there is a simpler way to proceed, study this simpler method. With the great advances in operative techniques and armamentarium, especially with the high speed machines, extensive prosthetic procedures have become a great temptation to general practitioners. As a result of this widespread practice of complete occlusal reconstruction, there are an increasing number of patients who are unable to adjust to this changed oral environment. Incorrect changes in the occlusal pattern can cause psychologic disturbances which can pose a more serious problem than the original occlusal defect.

In the stages of scientific development, first there is discovery and widespread, indiscriminate use. Then comes painful reappraisal, after which the true value is determined. This is attended with limitations for its use and its dangers. These must be fully understood so that one may be able to discriminate as to how and when to use the particular scientific development. A large number of our colleagues firmly believe that many periodontically involved cases have not been caused by occlusal trauma. Therefore, why not try all other means for eradicating this disease first before launching upon a journey from which, once started, there is no turning back. Hillman[2] and Young,[3] two orthodontists, believed that "the normal occlusion of the teeth conceived by the orthodontist to present 100 percent perfection is a myth. It has no biological justification or scientific foundation."[2] They also believed that "maximum continuous contact of the upper occlusal surfaces in all centric and excentric ranges does not occur in normal natural dentitions, or if it does, it is extremely rare."[3]

PROMISES TO PATIENTS

Let us be careful in the promises we make to our patients relative to wiping out the appearance of age. There is just so much that can be done to check the appearance of aging, and often this is not within our sphere of responsibility.

It is folly to believe that all temporomandibular joint pain and dysfunction are caused entirely by malocclusion. Schwartz[4] states that "the incidence of

organic involvement of the Temporal Mandibular Joint is low, and although its disfunction may be annoying or even painful, it is rarely serious." He seriously questions the belief that occlusal trauma is responsible for the majority of disturbances in the temporomandibular joint.

DENTITIONS IN MALOCCLUSION MAY BE IN EQUILIBRIUM

If a patient is not conscious of his oral organ, if he eats well, has no trouble with hearing, and has a moderately presentable occlusion, and if roentgenograms of the mouth are favorable for his age, be careful before undertaking complete oral reconstruction. A dentition may be in malocclusion, but it still may be in equilibrium, and to change it to our concept of occlusion may do the patient an extreme disservice. The best service that can be rendered to some of these patients is to leave them alone. For example, many patients with a deep vertical overlap are treated best by not changing the occlusion.

TOTAL RECONSTRUCTION VERSUS GOOD CONFORMATIVE DENTISTRY

Some patients cannot be treated simply. In these instances, the occlusion is badly broken down and the teeth have rotated and migrated; teeth are missing, and the patient is a dental cripple. This type of patient is not met as often as the patient who needs good conformative dental reconstruction built up to the type of occlusion he presents and to his present vertical dimension. It may not be possible to build the ideal occlusion, but the dentist can construct compromise restorations with the honest conviction that not only is he doing the patient a great service, but also that he is treading on safer ground. For this type of situation, conformative dentistry will provide for better function, enhance the chances of longevity, provide for lower costs, do the work in less time, and take less energy from both dentist and patient.

SPECIAL TECHNIQUES

We must guard against evaluating occlusal therapy in terms of some rigid mechanical concept. There is no one system that has a priority on perfection. There is no doubt that certain mechanical concepts can produce success for certain patients who have conditions peculiarly favorable for the application of a specific theory. However, to apply any given system to the infinite variety and broad area of our prosthetic problems is not only futile but dangerous. Our best assets are knowledge and personal skill. Progress means a search to make dental treatment easier to perform, while making it more successful and available to more people.

GOOD CONFORMATIVE DENTISTRY

Good conformative dentistry requires a great deal of knowledge of fundamentals. It embraces the use of study casts, clinical evaluations, roentgenographic findings, and a broad knowledge of the treatment of caries and of the periodontium. It involves knowledge about where to decrease cusp height and

inclines and how to straighten out the occlusal plane when there are extruded teeth. Pulpless teeth must be evaluated. Splinting may be necessary. All these and many more details must be considered in good conformative dentistry.

NEED FOR TOTAL ORAL RECONSTRUCTION

Those situations which are impossible to treat this way will have to be corrected by more difficult methods. Not only must the dentist be specially trained himself in order to treat these complicated situations by means of complete occlusal reconstruction, but specially trained technicians must be available in order to execute the complex details. Where this work is left to commercial dental laboratories, the results only aggravate an already difficult situation. The commercial dental laboratories are not at fault, but the dentist is unable to carefully prescribe and then watch the procedure being executed. The result is often far from satisfactory.

GOLD INLAYS, THREE-QUARTER CROWNS, AND SIMPLE ARTICULATORS

In good conformative dental techniques, there is less need for complete coverage and more need for gold inlays, three-quarter crowns, or pinlays. Although full coverage has its good features, the greater percentage of full crowns need acrylic resin veneers. This is a source of trouble relative to the longevity of the veneers and to color. In addition, full crowns with multiple splinting cause more periodontal inflammation than do inlays or three-quarter crowns. In complete oral rehabilitation, the full crown is used frequently because the position of the tooth needs changing. This is not the situation in conforming the restoration to the existing occlusion. Although the appearance may not be as esthetic when gold inlays are employed, those other advantages make them my choice in many of my conformative cases. Where conformative dental procedures are being used, the articulator is not necessarily as important an adjunct as when the dentist is creating an entirely new occlusal pattern. Here again, the ability to use a semi-anatomic articulator, or even a plane line or unilateral articulator, serves to make a laborious task simpler.

CONCLUSIONS

The longer one practices, the greater respect he has for the infinite variations which manifest themselves in the forms and in the functioning of the masticatory apparatus of the patients who present themselves for treatment. The greater their confidence, the larger our responsibility. Long experience dictates that many of the mouths which were rehabilitated would have been much better treated by simple *good* dental procedures. The test of time will remain the most eloquent testimonial to the effectiveness of any treatment procedure. Careful documentation over a period of more than 25 years gives one a hindsight that is much more intelligent than his foresight. This hindsight encourages those who will listen to continue to perform more and more good dental procedures with sound

mechanical and physiologic principles and to avoid, wherever possible, intricate and dramatic techniques. There is a tremendous difference between philosophy and clinical practice. Let us, therefore, adhere to sound principles, involve little risk, and do our work within safe bounds. In other words—be conservative.

REFERENCES

1. Webster's New Collegiate Dictionary, ed. 2, 1956.
2. Hillman, M.: Variations in Occlusion, D. Cosmos **63**:608-619, 1921.
3. Young, J. L.: Physiologic Occlusion, J.A.D.A. **13**:1089-1097, 1926.
4. Schwartz, L.: Editorial, New York State D. J. **25**:419-420, 1959.

730 Fifth Ave.
New York 19, N. Y.

SURVEY FOR COMPLETE PERIODONTAL PROSTHESIS

LEO TALKOV, D.M.D.*
Brookline, Mass.

THE BIOMECHANICAL CONCEPT has been well established in the diagnosis and treatment of the oral cavity.[1] Since such treatment in the periodontally infirm patient is particularly precarious, the dentist must employ every means for stabilizing the remaining teeth. Although only one aspect of the total therapeutic armamentarium, perhaps one of the most important is the splinting of periodontally involved teeth with fixed partial prostheses (Fig. 1). This is successful only if the prosthesis can be made firm by means of adequate reciprocal support.

Some of the engineering theories and principles in aligning multiple abutments were described previously.[2] Analysis of tooth to tooth relationships in the opposing arches as well as within the same arch, with all teeth prepared, reveals many components which should be considered before the impressions of the teeth are made. Not only will this point out necessary and plausible adjustments and reveal certain limitations within which the dentist may be forced to work, but it will afford him a preconceived picture of the result of the finished treatment. Technologic considerations at this time may also be taken into account.

PRECLINICAL CONSIDERATIONS

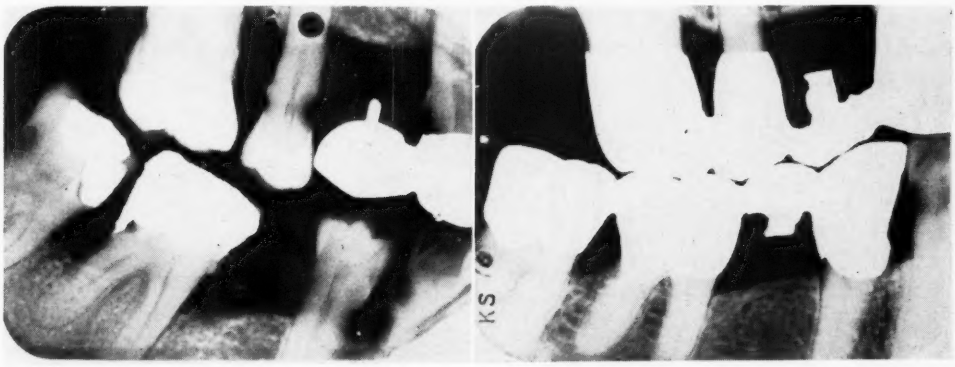
Prior to the preparation of the teeth, examination of the study casts is invaluable. In addition to parallelism, some of the influencing factors to consider are the amount of vertical and horizontal overlap, incisal guidance, intercuspation, plane of occlusion, cuspal inclination, and occlusion. If the vertical dimension of occlusion is to be altered, all of these factors will be changed in varying degrees.

CLINICAL PROCEDURE

As determined from the study casts, the axis most nearly common to all teeth is the guide for the preparations. By uncovering each preceding stage of the preparation at each succeeding appointment, the dentist has an opportunity to control the direction of parallelism as the work progresses. If necessary, parallelism may be checked precisely at any time by making an alginate impression of the entire dental arch (including the prepared and unprepared teeth) and pouring a cast in quick-setting plaster or artificial stone. Usually, one can gain enough information by "eye" alone to continue operative procedures, but the cast may be mounted for survey, if necessary.

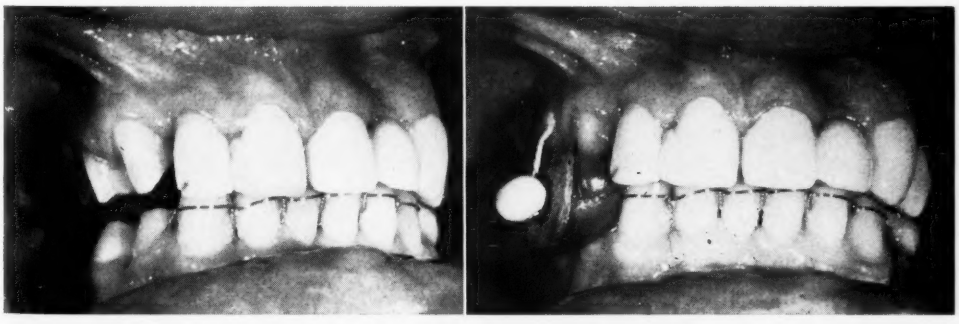
*Assistant Professor and Chairman of Prosthetic Dentistry, Department of Stomatology, Boston University, School of Medicine.

After all of the teeth of both dental arches are prepared, irreversible hydrocolloid impressions are made and poured in artificial stone. The gingival tissue need not be impeccably reproduced for this procedure. Then, with the temporary restorations opposing each other on one side of the mouth, the distance between the opposing exposed preparations on the other side of the mouth is observed. Softened wax is interposed between the preparations and an interocclusal centric relation record is made as the patient is gently guided to closure of the teeth (Fig. 2). The temporary restorations are replaced, and those on the other side of the mouth are removed. Again, softened wax is interposed between the preparations and the patient closes the teeth as before. All temporary restorations are then recemented, and the patient is dismissed. If all posterior teeth are missing in either or both dental arches, it may be necessary to use occlusion rims in order to make the records.



A. *B.*

Fig. 1.—*A*, The effects of loss of lower first molar without replacement. Note the tilting of the lower teeth with loss of contacts, the elongation of the upper second bicuspid with loss of contacts and proximal caries, the faulty restorations, the thickened periodontal membrane, the loss of bone height with undefined lamina dura, and the loss of character of supporting bone. *B*, The reconstruction of the teeth seen in *A* utilizing full coverage. Note the re-establishment of the occlusal plane, the corrected contact relationships stabilized by soldered joints, the proper crown contour and marginal fit, the thinning of the periodontal membrane, a well-defined lamina dura, and the normal trabeculation of supporting bone.



A. *B.*

Fig. 2.—*A*, The space between preparations on one side of the mouth is observed with the temporary restorations in position on the other side. *B*, The interocclusal wax record is made between the prepared teeth.

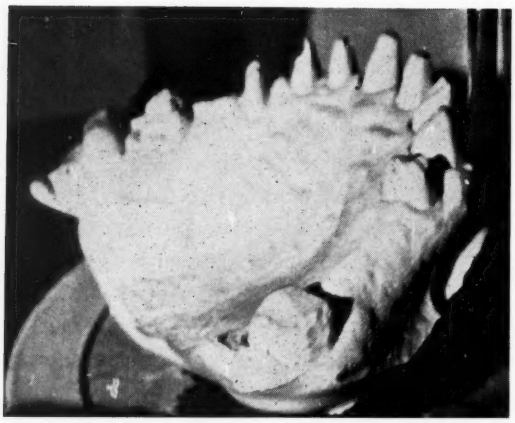


Fig. 3*A*.—The cast is surveyed. Note the tilt that favors the labial surfaces of the anterior teeth.

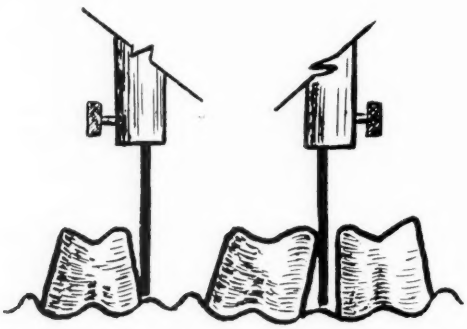


Fig. 3*B*.—The survey rod is properly related to the tooth on the left. An undercut is present on the tooth in the center.

SURVEY OF THE CASTS FOR PARALLELISM

Each cast of the prepared teeth is mounted on a movable base with a tilting device for survey (Fig. 3*A*). The inclination of the base is adjusted until the maximum surfaces taper away from the survey rod gingivo-occlusally (Fig. 3*B*). When no tooth or group of teeth is completely out of line, the labial surfaces of the anterior teeth must be favored (Fig. 3*C*). Posterior teeth lend themselves to greater alteration without incurring pulpal exposure. All interfering surfaces are recorded on the cast by circumscribing the part of the tooth to be adjusted in the mouth (Fig. 4). When complete parallelism is contraindicated because of the dangers of multiple exposures, parallelism is planned for groups of teeth with the intention of interlocking these groups with precision rests (Fig. 5).

Frequently, upper or lower protruding anterior teeth can be retruded by orthodontic means (Fig. 6). This serves to make them parallel to the posterior teeth and to enhance the appearance. The orthodontic treatment may be accomplished by placing a rubber band across the labial surfaces of the anterior teeth. The rubber band is attached to wires imbedded in the bicuspid region of the previously prepared

temporary acrylic resin posterior splints. The anterior teeth, if previously prepared, must remain as individual units with interproximal relief to allow for the retrusive movement. In the retrusion of upper anterior teeth, incisal relief of the lower anterior teeth must be provided.

When it is not possible to retrude the anterior teeth and sections are to be interlocked accordingly, there may be a choice in the division of the sections. For example, when only one or two upper teeth are missing, the survey may be altered to reveal a choice between planning two sections or three sections (Fig. 7). A survey is made for each section, and each is surveyed in a different color to show the division of the sections as well as the necessary adjustments in their respective colors. In this situation, technologic considerations may be the deciding factor.

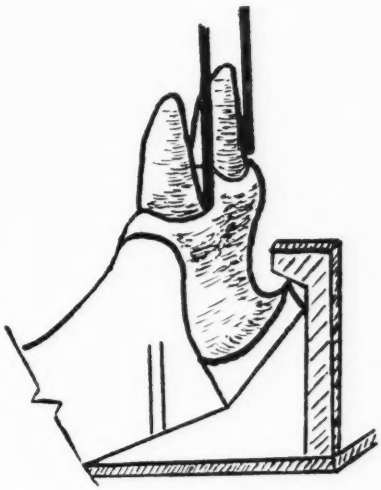


Fig. 3*C*.—The survey rod is properly related to the anterior teeth.

Fig. 4.—The original study cast and the surveyed cast of the prepared teeth guide the construction. Note the required adjustments to favor the labial surfaces of the anterior teeth.

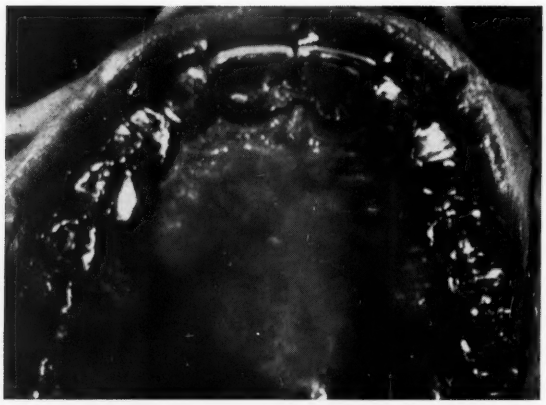
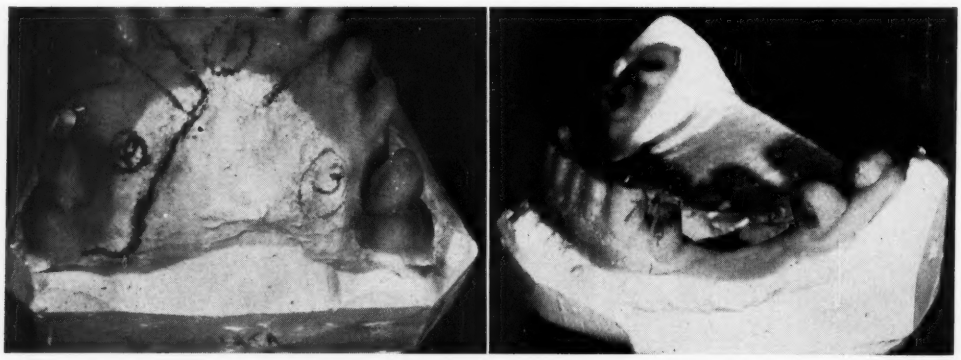


Fig. 5.—Two splinted sections are interlocked between the central incisors by means of a prefabricated precision male and female device.

A. *B.*

Fig. 6.—*A*, The extreme protrusions of the anterior teeth require orthodontic treatment. *B*, The protrusion is corrected to a position where splinting the entire dental arch in one unit is possible.



A. *B.*

Fig. 7.—*A*, A three section survey for a restoration with a choice of including the upper right first bicuspid in section 1 or section 2. The loss of the upper right second bicuspid, because of idiopathic resorption, necessitated the inclusion of the first bicuspid in section 2. *B*, A survey problem is present within a localized posterior section. The arrow on the unprepared cuspid indicates the necessity of a contact area adjustment. However, the likelihood of pulpal exposures necessitated planning the restoration in two sections.

The value of one malpositioned tooth must be determined as to its importance to the reconstruction. Then, the tooth may be moved orthodontically, its pulp may be exposed and treated by endodontic measures, or it may be extracted if necessary. It is impossible to parallel some lower anterior teeth that have extreme gingival recession. Here, each tooth is prepared on its own axis. The survey alone determines the location and number of interlocking sections (Fig. 8).

ARTICULATING THE CASTS

For purposes of study, the face-bow, hinge axis, and the patient's condylar path recordings are not used for the articulation of the casts. The casts are mounted empirically on a semiadjustable articulator such as the Hanau by means of the wax records.

Average condylar readings of 20 degree horizontal and 10 degree lateral inclinations are set on the articulator. If the vertical dimension of occlusion is to be changed, it is done by resetting the incisal (anterior) guide pin. Then, the incisal guidance is adjusted in harmony with the vertical and horizontal overlap of the anterior teeth as determined by whether or not balanced occlusion throughout or group function is the objective.

The space between the opposing preparations is observed in centric relation (Fig. 9). If more clearance is necessary for thickness of gold and/or noninterference with the proposed plane of occlusion, the surfaces of the teeth to be reduced are circumscribed in pencil.

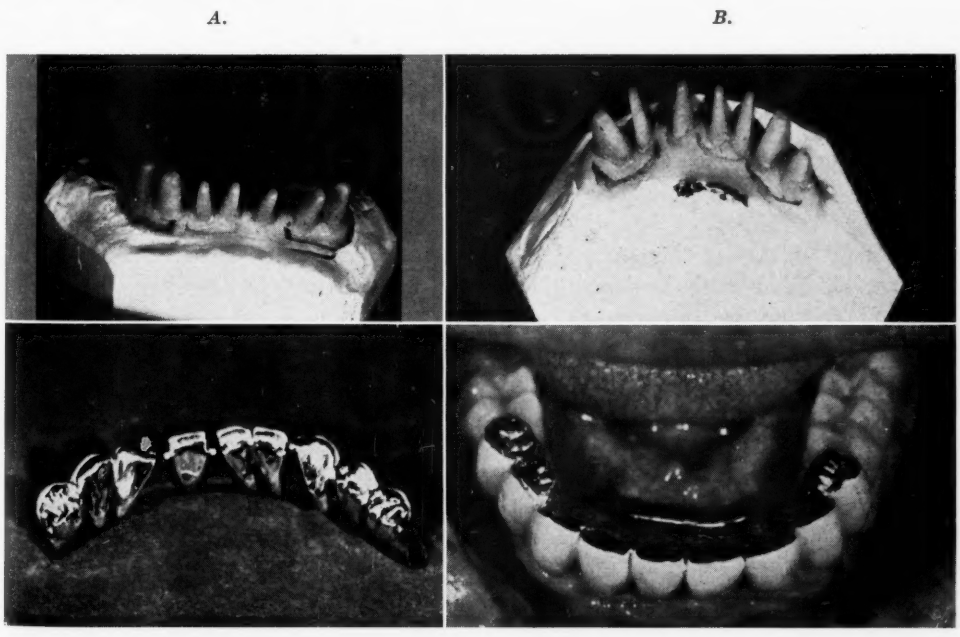
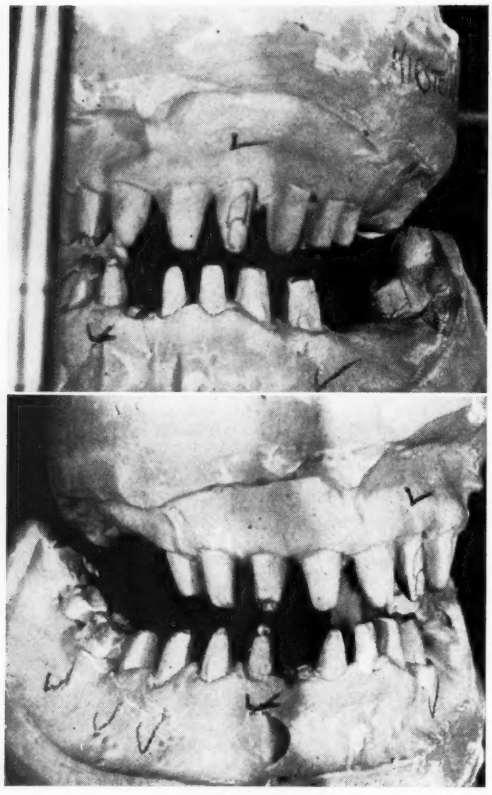


Fig. 8.—*A*, Each anterior tooth is prepared in relation to its own axis. Note the division into four sections. *B*, The lingual view of *A*. *C*, The restorations before insertion. Note the interlocking devices. *D*, The restorations are in the mouth.

A.



B.

Fig. 9.—*A*, The casts of the prepared teeth are articulated. Note the adequate distance between the opposing teeth. *B*, Incisal reduction of the upper and lower right lateral incisors is necessary for proper clearance in the left working position.

The articulator is then moved through its various excursions. Teeth which bypass each other with inadequate clearance are marked for reduction. Where posterior teeth do not intercuspate, it may be possible to make some adjustments of the cusps for this purpose. In addition, other observations such as soft tissue contours and structure (particularly of the ridges) might necessitate changes.

CONCLUSION

Articulated casts of the prepared teeth with all the indicated markings and recorded observations serve as a blueprint for the entire restoration before impressions of the prepared teeth are made. Any pathosis must be eliminated and all surgical, endodontic, or orthodontic treatment must be done prior to making impressions of the prepared teeth, regardless of impression technique. If an over-all elastic impression material is used, all tooth adjustments must be made first. If an individual tooth impression technique is used, the adjustments may be made one tooth at a time, just prior to making the impression.

Once a tooth adjustment is made, a checkmark is recorded on the cast opposite that tooth. This is particularly important when using an individual tooth impression technique, to eliminate the need of relying on one's memory from one visit to another. If the dentist decides not to make certain adjustments, the recordings as surveyed are kept for future reference. When the stage of articulated master casts with recordings is finally reached, before the wax-up procedure, it is with great satisfaction that the dentist can reflect upon the invaluable aid provided earlier by the articulated survey of the casts of the prepared teeth.

REFERENCE

1. Goldman, H. M., and Burket, L. W.: Treatment Planning in the Practice of Dentistry, St. Louis, 1959, The C. V. Mosby Company.
2. Talkov, L.: Lining Up Multiple Abutments, J. PROS. DEN. **1**:727-732, 1951.

1134 BEACON ST.
BROOKLINE 46, MASS.

PORCELAIN BONDED TO A CAST METAL UNDERSTRUCTURE

MILTON SILVER, A.B., D.D.S., MICHAEL C. HOWARD, C.D.T.,
AND GEORGE KLEIN, C.D.T.
New York, N. Y.

RECENT YEARS have seen the renaissance of porcelain in dentistry. Most of the impetus given to this rebirth is the result of the introduction of techniques that involve porcelain bonded to a cast metal structure.

Porcelain has been the material of choice whenever esthetic appearance was a consideration. Porcelain does have certain limitations, however. With the advent of the porcelain-metal combinations, these limitations (on the use of porcelain in dentistry) have been rapidly diminishing.

This article describes the technique for using a cast palladium alloy with a dental porcelain that has a matched coefficient of expansion baked on it.* The technique is the procedure which gives consistent results with the latest medium high-fusing materials.

INDICATIONS FOR PORCELAIN BONDED TO METAL RESTORATIONS

If a full coverage abutment retainer is indicated and the tooth is properly prepared, it is one of the best means of maintaining the health of the pulp. The use of full coverage restorations permits changes in contour and anatomic structure consistent with periodontal requirements, prevents further decay, and provides excellent retention. The palladium-porcelain restorations may be used for (1) anterior and posterior individual crowns with porcelain on all surfaces, broken-down crowns of teeth, fractured incisal angles or worn incisal edges, malformed and malposed teeth, discolored teeth, and carious and hypoplastic teeth (Fig. 1, *A* and *E*), (2) multiple splinting, (3) combinations of fixed and fixed-movable partial dentures (Fig. 2), (4) precision attachments and semiprecision locks and lug seats (Fig. 2), (5) situations in which anatomic conditions preclude the use of porcelain on all surfaces (metal occluding surfaces or porcelain veneer crowns are ideal) (Fig. 1, *B, C, G,* and *H*), and (6) abutments for removable partial dentures (Fig. 3).

The same qualities that indicate the use of palladium-porcelain restorations in extensive fixed partial denture restorations prompt their use in conjunction with removable partial dentures. The cast metal porcelain crowns offer resistance to abrasion by a partial denture with clasps. The porcelain will retain its shape and color, and desirable undercuts can be created in the contour of the porcelain for clasp retention. The employment of internal frictional attachments and the coil

*Micro-Bond, Austenal Inc., Chicago, Ill.

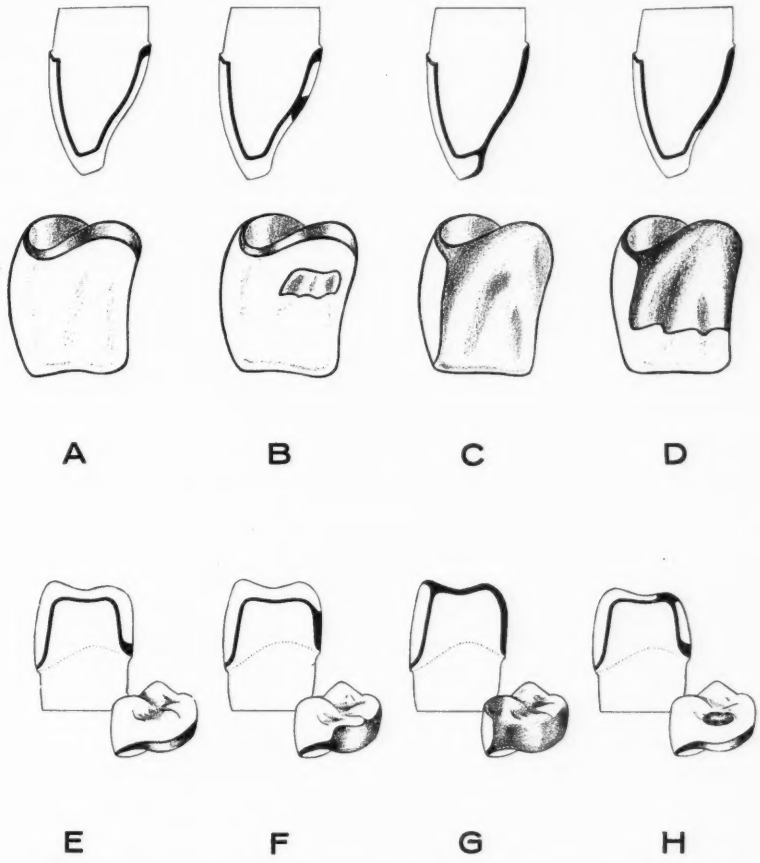


Fig. 1.—Various uses of porcelain bonded to metal restorations: (*A* and *E*) full porcelain coverage for anterior and posterior teeth—the anterior tooth preparation is of the beveled shoulder/chamfer type; (*B* and *H*) metal lingual surface and metal occlusal contact surfaces; (*C* and *G*) fused porcelain veneer crowns; (*D* and *F*) metal lingual surfaces.

spring attachment* for retaining removable partial dentures provides a physiologic restoration. Cast metal porcelain abutments that utilize these attachments offer the combined advantages of strength, durability, and esthetic appearance. The coil spring attachment is especially helpful when abutment teeth have short clinical crowns.

PREPARATIONS

The preparatory techniques and requirements for these restorations are not essentially different from other procedures used in modern restorative dentistry. Medium high to high rotational speeds are used. A copious water spray is used as a coolant and is mandatory. Adequate anesthesia and diamond instruments are used. In extensive operative procedures, intelligent use of sedatives and analgesics will minimize patient discomfort. A methodical, systematized approach to the preparation

*TACH-E-Z, Whaledent Inc., Brooklyn, N. Y.

of the tooth is essential. Each instrument should be used to its maximum capacity in an orderly sequence of steps. It should not be necessary to retrace steps using instruments previously removed from the handpiece.

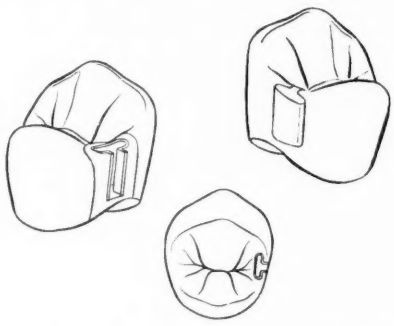


Fig. 2.—Precision attachments and semiprecision locks are within the metal-porcelain abutments.

The finished preparations must satisfy certain requirements particular to this type of restoration.

1. Sufficient tooth structure must be removed to allow the metal and porcelain to remain within the natural anatomic confines of the tooth. This will avoid gingival irritation and displacement after insertion.

2. The preparation must be shaped so that maximum protection is afforded to the pulp.

3. The preparation must provide sufficient support for the crown to withstand stresses under mastication.

4. Preparations should be free of undercuts and tapered slightly toward the incisal or occlusal surface to form a conical type of preparation.

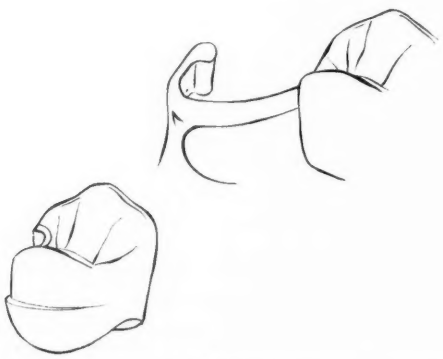


Fig. 3.—Clasps are used with metal-porcelain abutments.

5. An altered metal design can be created in situations where the occlusion does not allow sufficient space for the restoration.

6. Parallelism is critical to the success of this type of restoration since the materials involved possess no compensatory features, such as elasticity, which would normally overcome minor discrepancies in either unparallelism or undercuts.

A modified shoulder preparation is preferred. A well-defined shoulder about 1 mm. in width is made on the buccal or labial surfaces. This shoulder is joined smoothly to chamfered finishing lines, three quarters of the way into the proximal spaces and around the lingual margin (Fig. 4). The proximal and lingual surfaces in the region of the gingival margin usually are finished in metal, and the chamfer provides enough space without tissue impingement. The cavosurface of the preparation is beveled to eliminate a butt joint between the casting and the preparation. The shoulder should extend about 0.5 mm. under the gingival tissue if the depth of the gingival crevice permits (Fig. 5, *B*).

The generous buccal and labial shoulder allows enough thickness of porcelain to be placed in the critical gingival region to assure color fidelity without soft tissue irritation. An occlusal clearance of 2.5 mm. is adequate; where this cannot be

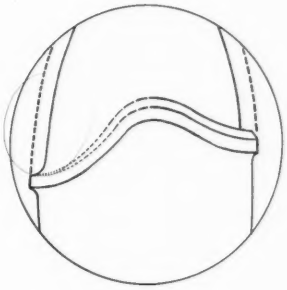


Fig. 4.—The recommended preparation. The labial or buccal beveled shoulder dissolves into a chamfer three-fourths of the way into the proximal surface and around the lingual surface.

secured, a metal occlusal surface may be used. Circumferentially, a provision of 1.5 mm. thickness will allow the construction of a jacket without excessive bulk.

Full shoulders may be made if desired (Fig. 5, *C*). However, there are many situations where a full shoulder circumscribing the tooth would endanger the pulp. An example is a molar with an excessive mesial inclination. The mesial surface, in such a situation, should have a finishing line even though the other surfaces may have definite shoulders. Lower anterior teeth that are slender and delicate should be prepared with a finishing line without a complete shoulder.

In multiple preparations, it is most important that the parallelism of the abutments to each other is true. The palladium-porcelain restorations will not tolerate a lack of parallelism of the preparations. Since dentists are accustomed to working with more flexible materials, such as gold and acrylic resin, some are likely to disregard a lack of parallelism even though the fit of the casting in the mouth disclosed it. Teeth are somewhat mobile, and the metal has some resiliency, so the metal casting may go into place. These two compensating factors will overcome a small degree of unparallelism. However, the unhappy consequence will come when the

porcelain is baked onto the metal frame. Porcelain, unlike metal or acrylic resin, has *no flexibility*. Where a splint has to give or bend in order to seat properly, the porcelain will fracture at that point. Abutments that cannot be made parallel by operative procedures alone (because they are either tilted, rotated, or malposed) must be handled carefully. Orthodontic treatment or the utilization of precision or semiprecision locks or telescoping crowns may be used to develop parallelism if necessary.

IMPRESSIONS, DIES, AND CASTS

Any impression technique that can produce accurate dies is adequate for the construction of palladium-porcelain restorations. The copper band–modeling compound technique is acceptable. The rubber-base impression materials used in copper bands produce accurate dies. The silicone materials are being used with varying success. Reversible hydrocolloid is accurate and can be used; however, the resultant stone die is vulnerable to distortion or damage during laboratory procedures. Metal or electroplated dies are preferred. Dies secured from any of the elastic impression materials must be carefully examined for undercuts, and if any are present, they should be carefully blocked out.

Where preparations are not quite conical in shape and multiple abutments are involved, it is advisable to paint the dies with a thin lacquer, keeping it away from

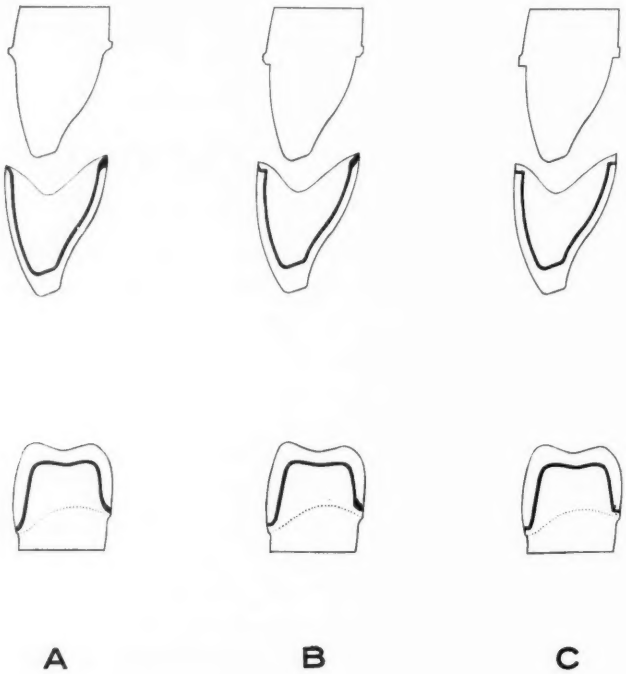


Fig. 5.—Anterior and posterior preparations: *(A)* the chamfer type of preparation, which is inadequate for anterior restorations; *(B)* the combination beveled shoulder and chamfer preparation; *(C)* the full shoulder preparation.

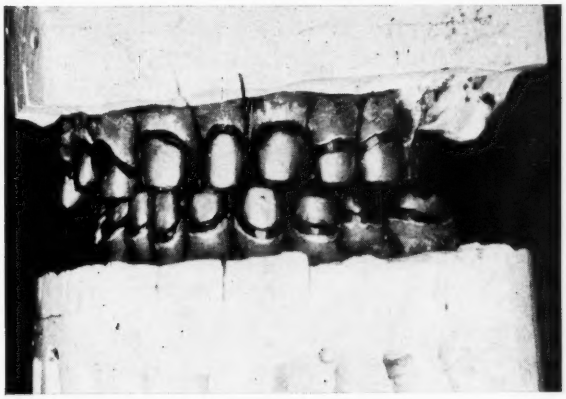


Fig. 6.—The wax-up on dies. Sheet wax is adapted to the dies, and the marginal seal is perfected with inlay wax.

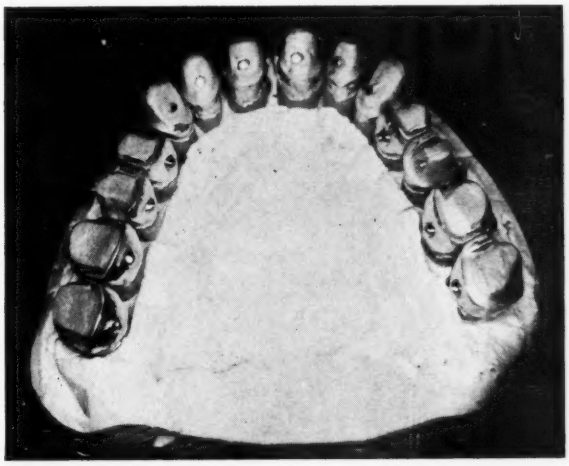


Fig. 7.—The metal castings on the dies. The posterior units are to be soldered together.

the margins and the occlusal surfaces. This will ensure a passive fit of the metal on the preparations and a close fit at the margins. All abutments for a restoration (a three unit bridge or a fourteen unit splint) should be waxed at the same time on the same cast. This will ensure a better design for the skeleton or framework, with an almost precise relationship at the connection points between the individual restorations.

WAXING THE METAL FRAMEWORK PATTERN

To wax the pattern for the coping, lubricate the die well and remove any excessive lubricant. A 26 gauge sheet of wax is adapted to fully cover the prepared area of the die without stretching any part of the wax (Fig. 6). The objective is a uniform thickness of wax. The sheet wax is adapted so as to reproduce minute

details on the surfaces of the preparation, particularly at sharp angles such as those of the shoulder preparations. Those areas where the wax may be stretched and also the margins are reinforced with inlay wax and carefully sealed. A lingual shoulder is built in wax. The lingual shoulder should be located about one-fifth of the distance up toward the incisal or occlusal surface from the gingival margin and should extend to the center of the proximal surfaces, mesiodistally.

This type of shoulder will serve to reinforce the entire metal structure and afford it maximum strength with minimum thickness. It also provides a reinforced connection point at the contact areas on the proximal surfaces for soldering. These connection points are provided only where the castings are to be joined together. It is advisable to extend the wax-up 0.25 mm. beyond the precise outline of the margins of the preparation. This provides a tolerance for casting, polishing, and fitting procedures.

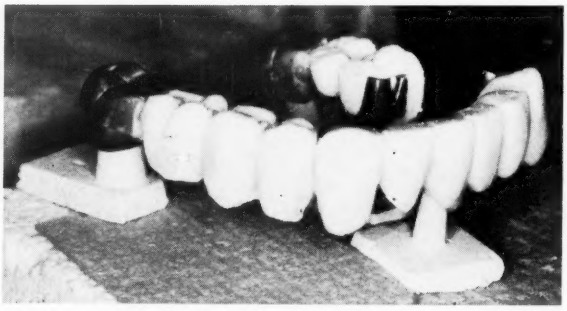


Fig. 8.—The first bake build-up is being dehydrated before the open muffle of the porcelain furnace.

Unlike in the unit built type of porcelain bridge, the connection points can be located where Nature intended them at the contact areas. They should be located approximately one-third of the distance from the incisal or occlusal surface to the gingival margin and well above the interdental papillae. This affords a physiologically correct design for a self-cleansing sluiceway without impinging the interdental papillae.

In waxing the artificial shoulders on the lingual surface, they should be kept at uniform thickness and should have a symmetric scallop design.

Where there is an excessive space at the occlusal surface or incisal edge, a major portion of this space should be filled by metal. Provision should be made for a fairly even thickness of porcelain (approximately 1.5 to 2 mm.). It is not desirable, even if the space is available, to provide for 4 to 5 mm. of porcelain at any one point. The strength of the restoration lies not in the porcelain or the thickness of the porcelain, but rather in the ideal combination of the cast metal structure and the specially compounded porcelain bonded to it. The porcelain is used only for esthetic purposes and not for strength.

The design and the placement of the pontics should be such that they will facilitate the work of the ceramist. The pontic should be positioned in a manner that will

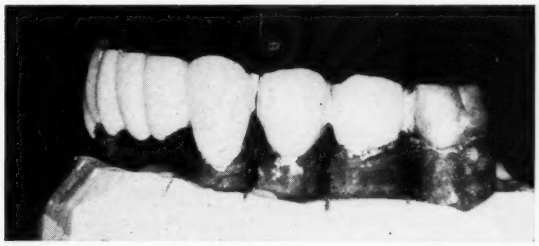


Fig. 9.—The first bake build-up after firing.

allow the ceramist to accomplish the following: (1) establish proper intercuspation of the occlusal surfaces, (2) establish proper occlusion with the opposing teeth, and (3) establish the desired curvature of the dental arch.

Esthetically, the pontics must be selected and located so that the ceramist will be able to restore the shape and alignment of the missing teeth in ideal proportions without interference from the cast metal understructure. They should allow him to bake a reasonably uniform thickness of porcelain on the surface of the castings. Structurally, the pontics must be designed so that the solder joints require a minimum of space and yet present a broad cross section contact area for the solder.

INVESTING AND CASTING

Since the palladium alloys have a casting temperature of almost 3,000° F., the casting and investing methods used are similar to those used for chrome-cobalt alloys. The casting is done in an all-silica refractory investment powder with tetraethyl silica investment liquid.[1] Several methods of melting can be used, such as high frequency, oxyacetylene, and oxyhydrogen.

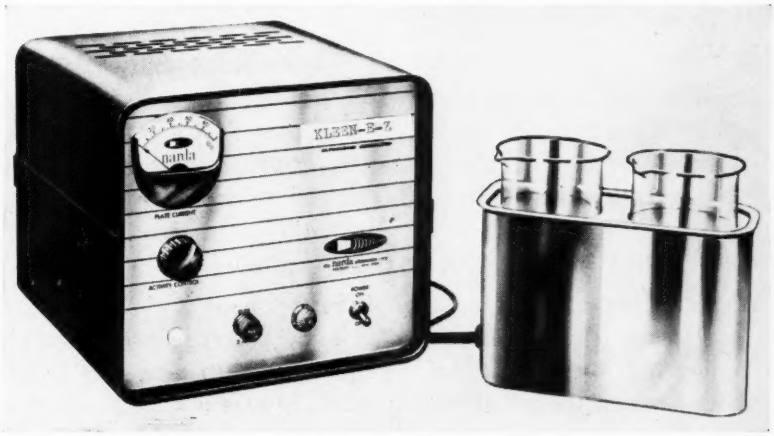


Fig. 10.—The ultrasonic unit for cleaning the metal and porcelain.

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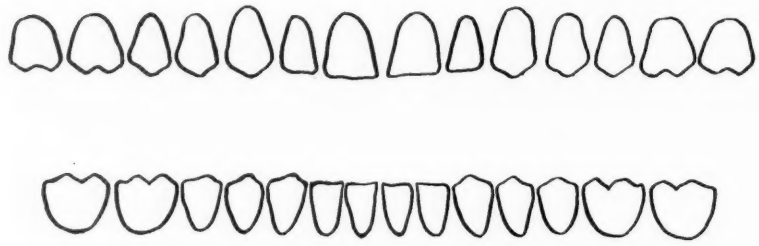


Fig. 11.—A correction chart for the ceramist.

FINISHING THE METAL AND SOLDERING

The alloy can be ground, fitted, finished, and polished with standard laboratory equipment and instruments such as are used for gold.

The cast units are connected together with a platinum solder* with a melting range of between 1,200° and 1,300° C. This range falls well below the melting ranges of the casting alloy and porcelains to be baked upon it subsequently.

CLINICAL NOTES CONCERNING THE METAL

Each individual coping or casting is fitted carefully to the tooth in the mouth. If the preparation was properly executed, there should be no doubt as to where the casting should terminate. Any overextension must be removed and verified with roentgenograms. Of course, all margins must be covered, and when multiple castings are tried in the mouth, adequate interproximal spaces should be provided. Impressions for joining separate units together are made in plaster of Paris. Connected spans are checked after soldering to test the accuracy of the fit of each coping in the span, marginal coverage, and accuracy of the span itself (Fig. 7).

THE PORCELAINS

The porcelain used in this technique is specifically compounded to be compatible with the metal.† When properly handled, it possesses all of the requirements for a dental porcelain. The palladium alloy–porcelain system embraces various premixed body shades, incisal shades, opaques, modifiers, and stains.

MANIPULATION AND FIRING OF PORCELAIN

The first step in the porcelain phase of the technique is the application of the undercoat or opaque. This undercoat is the same porcelain used throughout the porcelain system but is tinted in basic opaque shades to mask the metal understructure and to activate the initial shade control. In rare instances, where a critical

*Micro-Bond Platinum Solder or Baker's Platinum Solder.
†Micro-Bond Porcelain.

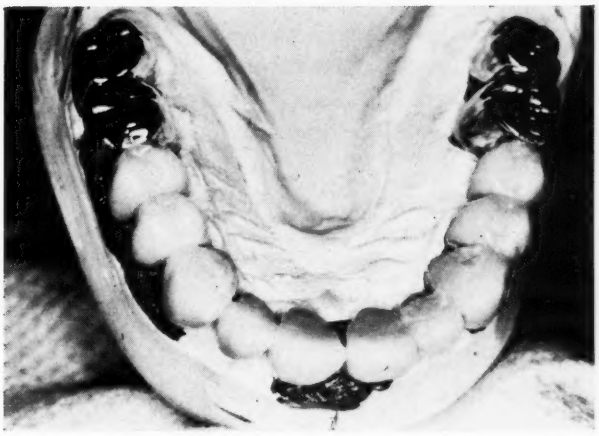


Fig. 12.—A molar to molar span employing cast palladium alloy crowns on posterior teeth.

shade is desired or the amount of porcelain to be applied must be kept at an absolute minimum, the shade of the undercoat can be altered by adding color concentrates.

The opaque porcelain is applied to the metal frame with a brush. The undercoat should be a fraction of a millimeter in thickness.

A properly baked undercoat will exhibit a uniform color and an eggshell finish with a *slight* satinlike sheen. There should be no hint of metal showing through.

BUILD-UP FOR THE FIRST BAKE

The desired body color and incisal porcelains are selected and mixed to a creamy consistency. The cast is soaked in water until it is saturated. This will prevent the stone cast from absorbing the moisture in the porcelain build-up.

Where a pontic is to be supplied, the edentulous area on the cast is lubricated with a vegetable oil, such as peanut oil, or a piece of facial tissue is used as a separator.

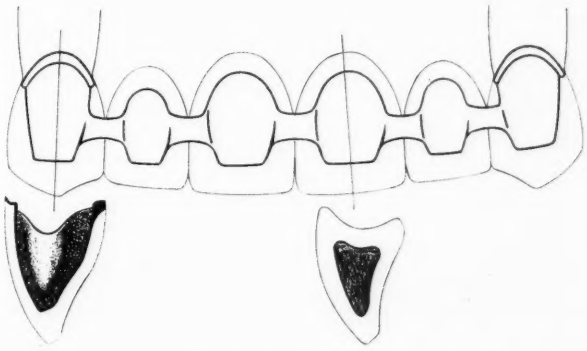


Fig. 13.—A cross section of a palladium-porcelain fixed partial denture. Note the porcelain under the pontics, the broad embrasures, connections, and the recommended tooth preparation.

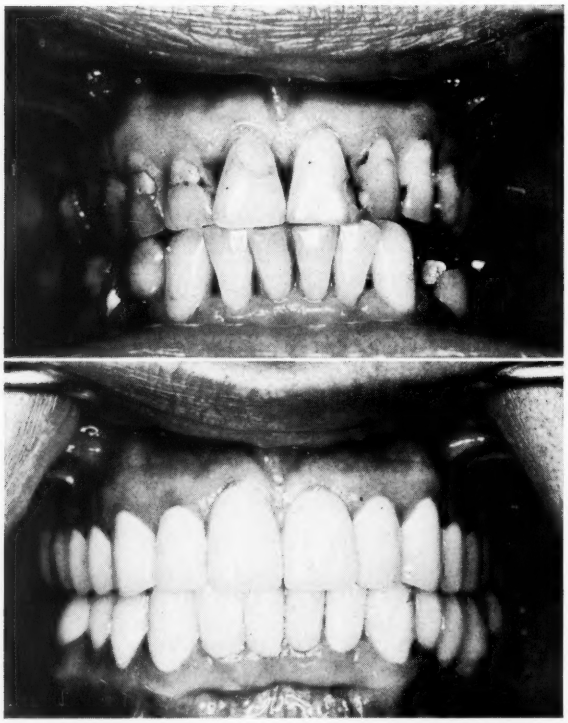
The gingival build-up is made and carefully condensed, packed, and vibrated to ensure proper firmness, bulk, or form. With a sharp carving instrument, the gingival build-up is cut away to accommodate the incisal porcelain. In doing this, keep in mind the desired effect and shape of the finished restoration. The proper shaping of the gingival form is one of the most influential factors in the control of the color of the restoration.

The gingival build-up is moistened, and the premixed incisal porcelain is applied. Again, the build-up is condensed, vibrated, and packed firmly. It must be kept in mind that excess vibration and moisture may distort the underlying gingival build-up. The incisal porcelain is worked constantly toward the body porcelain to ensure an integration of the two build-ups and the proper overlay of the incisal color over the gingival cone.

The build-up is then shaped and carved to the desired contour. Each tooth is carved individually and separated completely from the adjacent teeth by cutting entirely through the porcelain to the metal understructure. This will allow each porcelain unit to shrink within itself and avoid major cracks that result from shrinkage.

The metal framework is then removed from the cast. The abutment copings are inspected to make sure that no porcelain seeped inside of them. The metal

A.



B.

Fig. 14.—Palladium-porcelain restorations. *A*, The preoperative condition of the mouth. *B*, The completed restorations.

collars (on the lingual surface usually) are cleansed of all porcelain. The embrasures in fixed partial dentures are opened with a sharp instrument, and the tissue paper is stripped off the ridge surface of the pontics. Porcelain is then added to the mesial and distal contact areas to compensate for shrinkage. The amount of shrinkage caused by baking is relative to the bulk of porcelain and to the skill of the ceramist. The usual shrinkage is approximately 15 per cent.

The metal framework is placed on pegs and trays and dehydrated before the open muffle of a porcelain furnace until the porcelain is chalky white (Fig. 8). The porcelain is fired to 20° or 30° F. below the maturing point of the porcelain, which is approximately 2,000° F. A properly fused biscuit bake should have a granular appearance with no trace of chalkiness.

The metal framework is fitted back on the cast after the first bake. Any porcelain that may interfere with the proper positioning of the assembly on the die or cast is ground away. The contact areas and occlusion are adjusted and ground in with the stones and diamond instruments (Fig. 9). The porcelain is shaped to the desired contour. The assembly is then very carefully washed with a stiff brush, making sure that the porcelain is completely free of all foreign substances and residue that may have lodged in the pores of the porcelain during the contouring of the first bake. A high frequency cleansing unit* is excellent for removing impurities in the porcelain and/or metal.

THE SECOND BAKE

Using the same porcelains as before, the build-up is brought as close to anatomic and dimensional perfection as possible (Fig. 10). The interproximal separations are re-established, and the porcelain surfaces are brushed with a large sable brush to smooth them and to eliminate surface porosity.

Normally, the second bake, being an adjunct to the first bake, requires the addition of a minimum of porcelain; hence, its shrinkage is not a factor. The same firing cycle is employed as for the first bake. After the restoration has cooled, it is returned to the cast for final adjustment before the try-in in the mouth.

At this stage, the restoration is called the biscuit bake, and it is returned to the mouth for corrections. Articulating paper is used between individual porcelain units or between porcelain and natural teeth for evidence of binding. The contact areas must fulfill their requirements without interfering with the complete seating of the bridge or jackets. If pontics are present, the tissue side is examined by using disclosing wax for evidence of either tissue impingement or lack of tissue displacement. Once seated correctly, the span is examined in centric and eccentric occlusions and spot ground accordingly. The appearance and anatomic condition of the restoration are examined critically, and any changes are noted and corrected before the final (glaze) bake. If sufficient tooth structure was removed, there is no reason for excess bulk or exaggerated contour. The alterations and corrections should be carefully noted and described diagrammatically by the dentist. The use of a chart, such as Fig. 11, will facilitate the work of the ceramist.

*KLEEN-E-Z, Whaledent Co., Brooklyn, N. Y.

THE FINAL BAKE: CHARACTERIZING AND GLAZING

In preparation for the final bake, the restoration is thoroughly washed with a bristle brush, soap, and water. The minute pores of the biscuit bake porcelain are filled by brushing on a watery mixture of body porcelain and wiping it off completely with a tissue. Any characterization or special staining effects can be incorporated with the glaze bake by utilization of stains that mature at the same temperature as the basic porcelain. Postglazing corrections and additions to the restoration and special staining effects can be accomplished with low-fusing add-on porcelains, stains, and concentrates without affecting the basic porcelain after the glaze.

The porcelain is fired to develop its natural glaze. The correct firing cycle will influence the density and shading of the porcelain. Experience will determine how long to hold the porcelain at the glazing temperature. After cooling, the interior of each coping is checked for possible stray bits of porcelain which must be removed. Finally, the metal collars on the lingual surface of each restoration are polished (Fig. 12).

CEMENTATION

Restorations that consist of large spans should be cemented with a temporary cement until the adjustments are completed. The length of time temporary cementation is used depends upon each individual situation. No hard and fast rules can be laid down. The patient and the circumstances determine the course of action. The disadvantage of the temporary cements is that if they are truly temporary, they wash out with regularity. Thus, they encourage undesirable movement, loosening, and recurrent decay. If the patient can be recalled and the work checked and recemented regularly, these conditions might be kept under control. However, such procedures present almost insurmountable maintenance problems. After a short adjustment period, the palladium-porcelain restorations should be cemented with a permanent type of cement (Fig. 13).

MAINTENANCE

Palladium-porcelain restorations, like any other type of dental prosthesis, will at times require repairs. In our early experience with this type of full coverage restorations, the breakage problem was indeed a serious problem. However, today it is a small enough problem to be considered insignificant *in the light of the results achieved*. It is always easier to prevent breakage than to repair it. Recognition of the causes of fracture will lead to prevention. Some of the causes of fractures are:

1. Internal crazing or cracks in the porcelain that remain after the glaze bake. These are weak areas in the porcelain and should be removed.
2. Lack of parallelism of the abutments which causes torque in seating the restoration.
3. Overextension of a coping into an undercut.
4. Weakening of the porcelain by an excessive number of bakes or firings.
5. Poor preparation of the teeth and insufficient tooth reduction.

Small chips and breaks can be smoothed over and polished. If the span can be removed from the mouth, porcelain can be added to the defect and the section rebaked. This is a precarious solution since porcelain worn in the mouth may take on certain fluids that act detrimentally when subjected to refiring. A unit type of replacement is the best method for making repairs (Fig. 14).

SUMMARY

The use and construction of porcelain fused to a cast palladium alloy restoration has been discussed. The important clinical and laboratory procedures in the technique have been described.

REFERENCE

1. Weisman, S.: Personal communication, 1959.

75 East 55th St.
New York 22, N. Y.

CLASS V PORCELAIN INLAYS UTILIZING A CAST MATRIX

GEORGE T. COWGER, D.D.S.*
University of Texas, Dental Branch, Houston, Texas

CLASS V LOW-FUSING PORCELAIN INLAYS can be made to fit the cavity preparation more accurately than by conventional methods which involve the adaptation of a platinum foil matrix.

TECHNIQUE

Casting 1.—An inlay is cast to fit the cavity preparation, using a typical gold alloy. The sprue button is left on the casting for convenience in handling. The fit of the casting may be verified in the tooth before proceeding with the next step in the technique.

Casting 2.—A combination acrylic resin–wax pattern is formed to fit the cavity surfaces of casting 1. This pattern is cast in pure gold and must fit casting 1 accurately. The pure gold casting is thus a negative of casting 1, and it is a reasonably accurate reproduction of the cavity preparation.

Firing the Porcelain.—Porcelain is fired directly into casting 2. The porcelain is trimmed flush with the margins of the casting and refired in a porcelain oven to a suitable self-glaze.

Elimination of Gold Matrix.—The porcelain inlay is recovered from the pure gold negative (casting 2) by dissolving the gold in aqua regia. The loss of pure gold in this step is quite small, approximately one-half pennyweight for an average size class V inlay.

DETAILS OF THE TECHNIQUE

Cavity Preparation.—The cavity preparation is typical for a porcelain inlay. The outline form is one of gently flowing curves. The cavosurface angle is not sharply beveled. The finish of the cavosurface angle can be completed by polishing it with finishing strips, which will leave a smooth finish with no unsupported enamel rods. A long bevel on the margin would cause the porcelain inlay to have a sharp,

Presented before the American Academy of Crown and Bridge Prosthodontics, Chicago, Ill.
*Associate Professor of Restorative Dentistry.

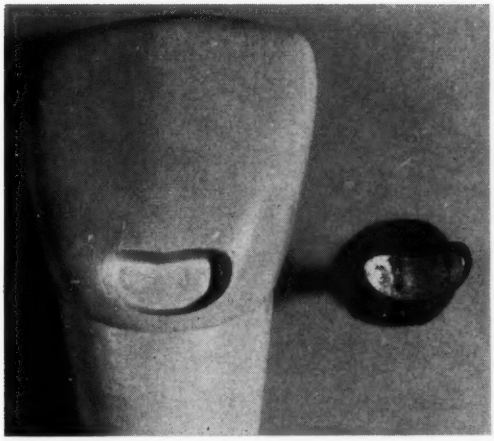


Fig. 1.—The cavity preparation and casting 1, the negative record made of the cavity preparation.

thin, almost transparent margin. Such a margin is easily fractured, and the cementing substance shows through the inlay (Fig. 1).

Casting 1.—The pattern for this casting can be waxed directly in the mouth or made by an indirect method. Special care should be taken to carve the wax so that there are no overhanging or ragged margins. The sprue button is left attached and the casting can be tried in the mouth to verify the fit before proceeding with the next step (Fig. 1).

Casting 2.—This casting is made of pure gold, and it forms the matrix for firing the low-fusing porcelain. With some practice, it is not difficult to form a pattern which fits casting 1. Cold-curing acrylic resin is painted onto the cavity surfaces of casting 1 up to the labial margin. The pattern is built up with a small brush, alternately adding small amounts of monomer and polymer. The labial surface and labial margin of casting 1 are not covered. The labial margin is avoided because overhanging acrylic resin will prevent casting 1 from being withdrawn from the

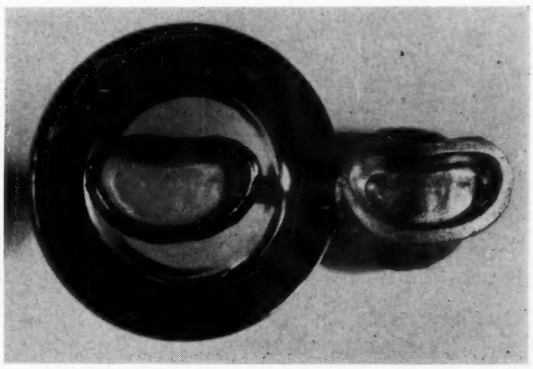


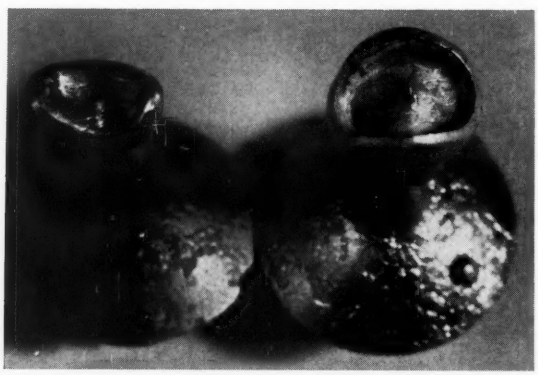
Fig. 2.—The acrylic resin–wax pattern made on casting 1 and the pure gold casting 2 made from it. Casting 2 is the positive reproduction of the cavity preparation.

pattern. The finished castings in Fig. 4 illustrate this point. A metal sprue is firmly attached to the base of the acrylic resin pattern by means of the acrylic resin monomer and polymer.

When the acrylic resin has set, casting 1 is drawn out of the pattern, then replaced. The initial separation of the acrylic resin pattern from casting 1 requires considerable force. The sprue button of casting 1 and the metal sprue attached to the pattern serve as handles for this forcible separation.

After replacing casting 1 in the acrylic resin pattern, the labial surface and margin are refined with inlay wax by adding the molten wax directly to the resin. The surface is then carved down flush with the labial surface of casting 1. This step is done carefully, and there must be no wax or acrylic resin overhanging the labial surface of casting 1 which would prevent the withdrawal of the finished pattern (Figs. 2, 3, and 4).

The side walls of the acrylic resin wax pattern need only be thick enough to resist distortion, possibly 1 mm. This pattern is now a negative of casting 1. The metal sprue pin attached to the pattern is given a coat of wax to enlarge it as much as desired for casting. The metal sprue pin will drop out of the investment when the acrylic resin–wax pattern is burned out in the casting oven. *Pure gold* is used to make the casting.



A. *B.*

Fig. 3.—*A*, Casting 1. *B*, Casting 2.

CHOICE OF MATRIX METAL

After experimentation with various casting metals, it was found that pure gold was the best material for making casting 2. Its fusing point is sufficiently high to serve as a matrix for the low-fusing porcelain, and it was the only metal which did not affect the color of the fused porcelain. Pure gold can be cast with reasonable accuracy, whereas it was difficult to get accurate castings with some of the platinum-gold alloys. Finally, aqua regia attacks the pure gold readily so the elimination of the gold matrix is no problem.

After casting, the sprue button is left attached to casting 2 until after the porcelain has been fired. The pure gold casting need not be pickled, but it must be mechanically cleansed thoroughly to remove all of the refractory investment.

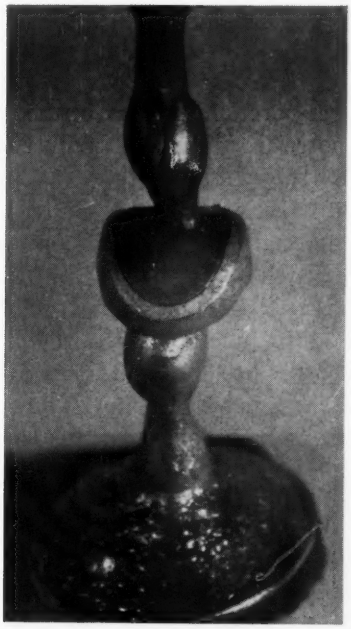
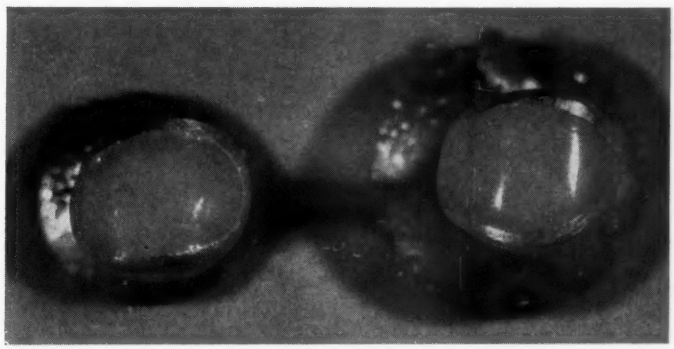


Fig. 4.—Casting 1 is fitted into casting 2.

The fit of the finished porcelain inlay depends mainly upon (1) the accuracy with which casting 1 fits the preparation in the mouth, (2) the accuracy with which casting 1 fits casting 2, and (3) careful trimming of the porcelain to the margin of casting 2 after the porcelain has been fired and is ready for the self-glaze firing.

FIRING THE PORCELAIN

Permadent or Ceramco porcelain is used, because either can be fused and glazed substantially below the melting point of the pure gold casting. The shrinkage of the porcelain is controlled by building the first application "high" on the walls



A. *B.*

Fig. 5.—*A*, The inlay after the second firing. *B*, The porcelain has been ground flush with the gold margin of casting 2 and refired to the self-glaze.

of the gold cavity, covering the margin slightly and leaving the center part underfilled.

The porcelain should be vibrated and blotted several times as it is built up in the matrix. Enclosing the wet porcelain powder in the pure gold matrix can cause "steam explosions," so the porcelain in the matrix must be dried for several minutes in front of the open oven door before it is "fired."

The porcelain and its matrix can be placed in the oven at or below 1,100° F. Each bake is carried up approximately 100° F. per minute, to a temperature of 1,700° F., where it is held for 1 minute. After the firing, it can be immediately bench cooled, since the hot metal cools at a slow enough rate to keep the fused porcelain from cracking. If the porcelain has been applied correctly, the margin will be slightly covered after the first firing. The shrinkage will have taken place toward the cavity walls, leaving a depression in the center. Thus, in a few minutes, the crater can be filled with more porcelain powder and refired with a minimum loss of time.

After the second firing, the porcelain is carefully inspected for deficiencies. If satisfactory, the porcelain is carefully ground back to the level of the margin of the gold matrix in preparation for the final glaze firing. Meticulous care must be exercised in this step. Undertrimming will leave overhanging margins on the finished inlay, and overtrimming will submerge the margins of the inlay below the cavity margins. The porcelain is smoothed, scrubbed under running water, and fired to a self-glaze (Fig. 5).

After bench cooling, the gold matrix is ground thin in all dimensions with stones and disks, making certain that the porcelain is not touched by these instruments. The sprue button is removed and the porcelain inlay in the remnant of its gold matrix is placed in aqua regia overnight to remove the remaining metal. Upon recovery of the porcelain inlay, it should be well scrubbed to remove all traces of acid.

The inlay is relieved slightly to allow space for cement and to enable the dentist to seat it without tapping against the porcelain. A small mounted stone point is used for this relief. Care is taken to make certain that the labial margin of the inlay is not altered.

An alternate method for providing the space for cement is possible. Before the acrylic resin–wax pattern is formed, casting 1 can be polished *slightly* on its axial and pulpal walls. Care must be taken to avoid alterations of the margins of the labial surface. When the acrylic resin–wax pattern is formed on the modified casting and cast (casting 2), the gold matrix thus shaped will provide the necessary relief. The porcelain inlay will be automatically provided with space for the cement.

CEMENTATION

After the fit of the porcelain inlay has been verified, the inlay is cemented in place with oxyphosphate of zinc cement. The consistency of the mix should be that used to seat a porcelain jacket crown. The color of the cement to be used can be determined by mixing various shades of cement powder with water or glycerin and observing them in the mouth with the inlay.

Heavy finger pressure is used to seat the inlay after the cement has been applied to the cavity, or the pressure can be applied to the inlay with the rubber eraser on a lead pencil. The area of the mouth around the inlay must be kept dry until the cement is completely set.

SUMMARY

A technique for making porcelain inlays has been described. A cast gold matrix is formed for firing the porcelain. The method eliminates the need for a platinum foil matrix and avoids the difficulties involved in their formation and use.

University of Texas
Dental Branch
P. O. Box 20068
Houston 25, Texas

INFLUENCES OF CLINICAL VARIABLES ON A CRISTOBALITE INVESTMENT

TAKAO FUSAYAMA, D.D.S., D.M.Sc.,* HIROYASU HOSODA, D.D.S.,**
AND V. M. KHER, D.D.S., L.D.S.***
Tokyo Medical and Dental University, Tokyo, Japan

INVESTMENT EXPANSION is the most important compensation for the casting shrinkage of a dental alloy. The investment expands during setting or heating. However, a large normal or hygroscopic expansion during the setting phase results in distoration of wax patterns and inconsistent dimensional accuracy.[1] A new method of controlling expansion was developed with the use of thermal expansion and dry asbestos lining.[2,3]

The influences of clinical variables on the properties of the cristobalite investment should be known so that desirable results can be consistently secured with this thermal expansion technique. Therefore, the influences of certain variables on a cristobalite investment used in Japan† with the thermal expansion technique were investigated. The variables tested were (1) water/powder ratio, (2) various chemicals in the mixing water, (3) time lapse before heating, (4) rate of heating, (5) underheating or overheating, and (6) cooling and reheating.

The investment was thoroughly hand spatulated with distilled water in a rubber bowl for a period of 1 minute at approximately 100 r.p.m.

MEASUREMENTS

Setting Time.—The initial setting time was measured with a Vicat needle.

Setting Expansion.—The vertical measuring apparatus devised by Fusayama[4] was used for measuring the setting expansion (Fig. 1). The metal box for molding investment specimens was 23 mm. square at the top and bottom and 50 mm. in height. The side walls were removed as soon as the Vicat needle indicated the initial set. The vertical expansion was measured continuously with a dial indicator having approximately 50 Gm. spring pressure. The design and the method of using the apparatus were previously described by Fusayama.[4]

Thermal Expansion.—A cylindric investment specimen 50 mm. long and 10 mm. wide was constructed (Fig. 2). Tinfoil was adapted to the inside walls of the two parts of the cylinder for easy separation. Then the two pieces were placed into the base. The investment mix was poured into the tube mold, and the specimen was removed from the mold immediately after the initial set.

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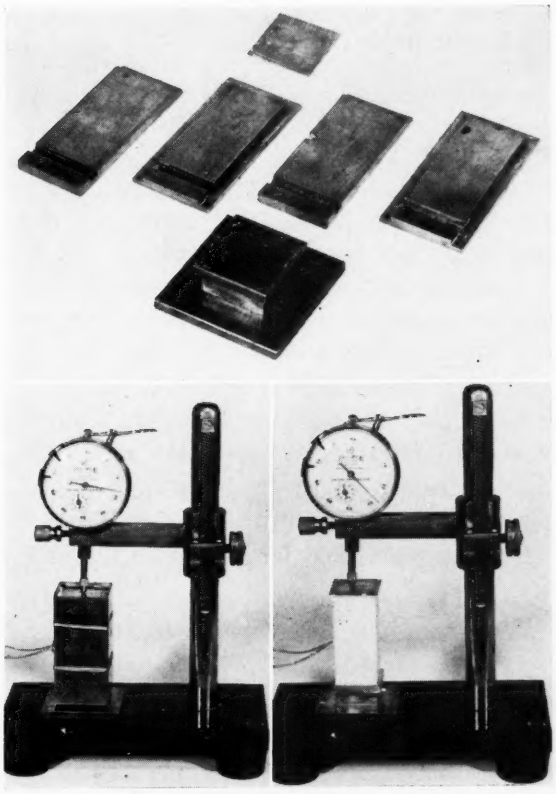
*Assistant Professor of Operative Dentistry.
**Instructor.
***Colombo Plan Scholar from India; Professor of Operative Dentistry, Nair Dental Hospital, University of Bombay.
†Shofu Cristobalite Investment (Batches 548 and 567), Shofu Dental Mfg. Co., Japan.

A.



B. *C.*

Fig. 1.—The vertical apparatus was used for measuring the setting expansion of gypsum products. *A*, The separated pieces of the box are assembled for molding specimens. *B*, The investment is poured in the mold which is tied with two rubber rings. *C*, The side walls are removed immediately after the initial set to allow free expansion.

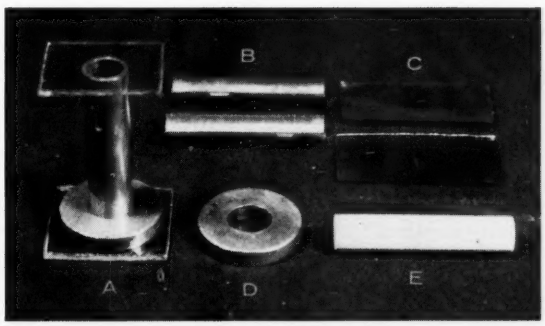


Fig. 2.—*(A)* A set tube with glass covers on the top and bottom is ready for pouring with investment mix; *(B)* separated pieces of tube; *(C)* tinfoil to cover the inside surface of the tube; *(D)* base to hold the tube; *(E)* cylindric investment block (specimen) of 50 mm. length and 10 mm. diameter.

The specimen was heated to either 700° or 800° C. in a horizontal electric furnace to measure the thermal expansion. Thermal expansion was determined with a dial indicator and a thermocouple (Fig. 3).

CASTING TEST

A "square plate" stainless steel mold[1] was used for molding wax patterns and measuring dimensional changes of castings (Fig. 4). Patterns were made of paraffin wax with a "press-molding" technique.[1] The patterns were invested as soon as possible after removal. The inner diameter of the casting ring was 30 mm. and the height was 38 mm. The rings were lined with four layers of soft dry asbestos 0.4 mm. thick.* The surface of the asbestos lining was coated with cocoa butter to prevent absorption of water from the investment mix.[3]

The invested rings were heated in an electric furnace and cast centrifugally with dental copper alloy.† This alloy had a 2.1 per cent casting shrinkage in this square plate form, which is comparable to regular inlay gold alloy.

The castings were examined with both the naked eye and a microscope. The dimensional changes were measured with the original mold. The design and the method of using the square plate mold for measuring the dimensional changes of castings were previously described.[1]

Fig. 3.—The specimens are heated in a horizontal measuring furnace: *(A)* the furnace; *(B)* the couple; *(C)* the dial indicator; *(D)* the pyrometer; *(E)* the voltage regulator.

VARIABLE EXPERIMENTAL CONDITIONS

The standard water/powder ratio was 0.35. Ratios of 0.33, 0.37, and 0.39 were also tested for determining the influence of variable ratios.

Distilled water was generally used for the investment mix. Various chemicals were added to the water prior to mixing in some groups to produce desired setting

*Shofu Asbestos Ribbon, Shofu Dental Mfg. Co., Japan.
†Progold, Hayashi Alloy Company, Japan.

and thermal expansions of investment. Various concentrations and combinations of sodium chloride, potassium chloride, sodium sulfate, and sodium fluoride were used as accelerators, while borax was used as a retarder.

The standard time lapse between mixing and the beginning of heating was 1 hour. Specimens were also heated either 12 minutes (immediately after the initial set), 30 minutes, 2 hours, 3 hours, 4 hours, 6 hours, 1 day, or 2 days from the moment mixing was begun to determine the influence of varied time lapses.

The standard rate of temperature rise for the investment was 10° C. per minute. The temperature of some specimens was raised 10° C. either every 15 seconds, 30 seconds, 2 minutes, or 3 minutes to determine the influence of varied rates of temperature rise. One group was held at 700° C. for 30 to 120 minutes after heating at the standard rate.

In some groups, the specimens were overheated to 850° C. Some specimens were cooled after heating and reheated to the original high heat temperature. Thus, the influence of underheating or overheating and of cooling and reheating was investigated.

WATER/POWDER RATIO

Results from varied water/powder ratios are shown in Table I. The temperature change from 18° to 28° C. or the humidity change from 60 to 80 per cent produced no significant change in either the setting time, the setting expansion, or the thermal

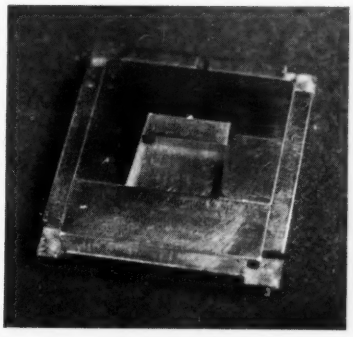


Fig. 4.—The square plate mold is used for molding wax patterns and measuring dimensional changes of castings.

expansion of the investment (batch 548). These results compare favorably with the results Skinner[5] reported with the use of plaster.

The means of the results from the four groups are compared in Table II. An increase of the water/powder ratio from 0.35 to 0.37 delayed the initial set by 1 minute, decreased the setting expansion by 0.06 per cent, and decreased the thermal expansion by 0.11 per cent. A ratio either greater or less than this range (0.35 to 0.37) was too dry or wet to be clinically usable. Measurement of investment and water with a scoop and a cylinder may be clinically satisfactory since their use caused a deviation of water/powder ratio less than 0.1 per cent.

TABLE I. INITIAL SETTING TIME AND EXPANSION OF THE CRISTOBALITE INVESTMENT (BATCH 548), WITH DIFFERENT WATER/POWDER RATIOS AT VARIOUS ROOM TEMPERATURES AND RELATIVE HUMIDITIES

TEMPERATURE (°C.)	HUMIDITY (%)	WATER/POWDER RATIO	SETTING TIME (MIN.)	EXPANSION (%)		
				SETTING	THERMAL	TOTAL
23	76	0.33	7	0.49	1.37	1.86
23	80	0.33	8	0.52	1.45	1.97
18	70	0.33	8	0.56	1.40	1.96
18	72	0.33	9	0.52	1.40	1.92
22	64	0.33	8	0.54	1.35	1.89
23	81	0.35	10	0.44	1.33	1.77
20	65	0.35	10	0.47	1.31	1.78
28	71	0.35	10	0.46	1.33	1.79
20	72	0.37	11	0.40	1.25	1.65
23	60	0.37	11	0.41	1.19	1.60
23	60	0.37	11	0.40	1.20	1.60
23	72	0.39	12	0.38	1.13	1.51
19	70	0.39	12	0.37	1.12	1.49
22	62	0.39	12	0.37	1.12	1.49

TABLE II. EFFECT OF WATER/POWDER RATIO ON PROPERTIES OF THE CRISTOBALITE INVESTMENT (BATCH 548)

WATER/POWDER RATIO	SETTING TIME (MIN.)	EXPANSION (%)			CONSISTENCY OF MIX
		SETTING	THERMAL	TOTAL	
0.33	8	0.53	1.39	1.92	Too dry
0.35	10	0.46	1.32	1.78	Adequate
0.37	11	0.40	1.21	1.61	Adequate
0.39	12	0.37	1.12	1.49	Too wet

ADDITIONS OF CHEMICALS

Approximately 0.05 (0.04 to 0.07) per cent[1] is the ideal setting expansion of investment. This expansion prevents wax pattern distortion and obtains consistent mold expansion. Such an investment is essential for measuring casting shrinkage of cast restorations. Therefore, the first objective was the development of an investment with an approximate 0.05 per cent setting expansion.

The ideal total expansion of investment for clinical use is approximately 1.6 per cent when using an indirect die which expands 0.5 per cent outside.[2] Thus, an investment with 0.05 per cent setting and 1.55 per cent thermal expansions is considered ideal. Development of such a clinically ideal investment was the second objective.

Moore[6] has shown that sodium chloride accelerates the setting expansion and increases the thermal expansion of gypsum investment. Borax is a commonly used

retarder and at the same time reduces the setting expansion of gypsum products.[5,7] Some sulfates or chlorides of various metals are known as accelerators, but most of them also reduce the setting expansion.[5,7]

Borax and various known accelerators were mixed in this study. Sodium fluoride was also tested as an accelerator. It might be an effective accelerator since it has a melting point (992° C.) higher than regular casting temperature and since the fluorine atom is the smallest halogen.

Table III shows the setting time, expansion, and cast surface conditions of the cristobalite investment (batch 548) when mixed with water that contained various chemicals. Representive curves of setting and thermal expansions are shown in Fig. 5.

Sodium fluoride was the most powerful restrictive agent of setting expansion. An investment with a setting expansion as little as 0.06 per cent and yet with adequate setting time was developed by adding 0.4 per cent sodium fluoride and

TABLE III. EFFECT OF ADDING CHEMICALS IN MIXING WATER ON THE PROPERTIES OF THE CRISTOBALITE INVESTMENT (BATCH 548) AND CAST SURFACES (WATER/POWDER RATIO = 0.35)

ROOM TEMPERATURE (°C.)	CHEMICALS ADDED IN WATER (%)					NUMBER OF TESTS	SETTING TIME (MIN.)	EXPANSION (%)			CAST SURFACE
	BORAX	NaCl	KCl	$NaSO_4$	NaF			SETTING	THERMAL	TOTAL	
20						2	10	0.47	1.31	1.78	Smooth
17		2.0				2	4	0.46			
18	0.3	2.0				1	14	0.15			
18	0.6	2.0				1	18	0.08			
18	0.7	2.0				1	27	0.06			
18	0.6	3.3				2	14	0.07			
18	0.6	3.5				2	13	0.07			
21	0.6	3.3	0.4			1	14				
21	0.6	3.3	0.8			1	15	0.04	1.53	1.57	Rough
21	0.6	3.3		1.0		1	10	0.04			
21	0.6	3.0		1.0		1	10	0.06			
21	0.6	2.0		1.0		2	10	0.05	1.42	1.47	Rough
27	1.0				0.6	1	10	0.03	1.15	1.18	
27	0.8				0.5	1	8	0.05			
27	0.8				0.4	2	9	0.06	1.27	1.33	Smooth
27	1.0	0.5			0.5	2	11	0.02			
27	0.9	0.5			0.4	1	11	0.04			
27	0.9	0.5			0.3	1	12	0.04	1.37	1.41	Rough
27	0.9	1.0			0.2	2	13	0.04	1.41	1.45	
26	0.9	1.5			0.3	1	10	0.04			
26	0.9	1.5			0.1	1	16	0.02			
26	0.8	1.5			0.05	1	14	0.04	1.48	1.53	
26	0.7	1.5			0.05	1	12	0.06			
27	0.8	1.5			0.1	4	12	0.05	1.47	1.52	
26	0.8	2.0			0.1	2	10	0.05	1.53	1.58	Rough

0.8 per cent borax to water. This investment was suitable for a casting shrinkage test because it distorted wax patterns least and achieved the most consistent mold expansion. Metal surfaces cast with this investment were smooth. However, sodium fluoride increased the thermal expansion very little, if at all, while sodium chloride, potassium chloride, and sodium sulfate considerably increased thermal expansion.

An investment with a clinically adequate setting time and approximately 0.05 per cent setting and 1.55 per cent thermal expansions was produced by (1) adding 0.6 per cent borax, 3.3 per cent sodium chloride, and 0.8 per cent potassium chloride or by (2) adding 0.8 per cent borax, 2.0 per cent sodium chloride, and 0.1 per cent sodium fluoride. However, the second investment roughened the cast surfaces.

TIME LAPSE BEFORE HEATING

The thermal expansion at 700° C. when the investment (batch 567) was heated in the furnace after various time lapses from the beginning of the mix is shown in Table IV. The thermal expansion curves from representive groups are compared in Fig. 6.

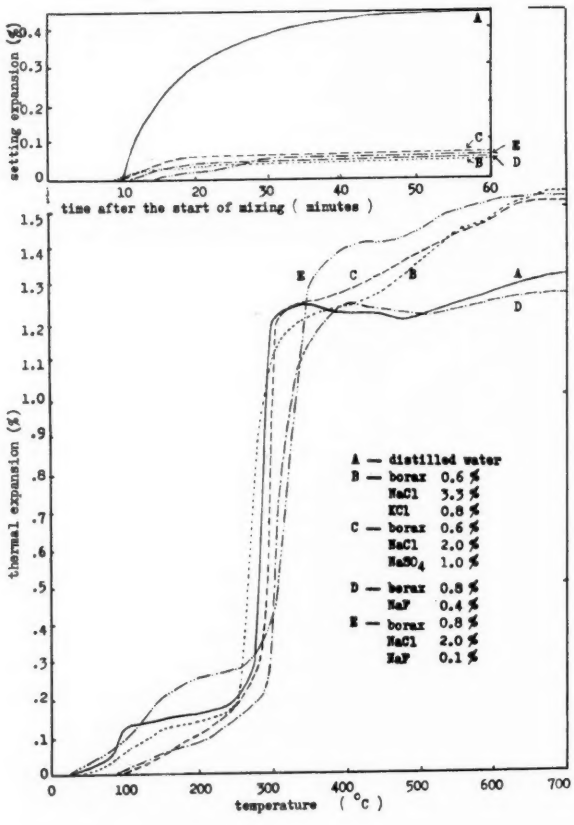

setting expansion (%)
time after the start of mixing (minutes)
thermal expansion (%)
temperature (°C)
A — distilled water
B — borax 0.6 %
NaCl 3.3 %
KCl 0.8 %
C — borax 0.6 %
NaCl 2.0 %
NaSO4 1.0 %
D — borax 0.8 %
NaF 0.4 %
E — borax 0.8 %
NaCl 2.0 %
NaF 0.1 %

Fig. 5.—Expansion of the investment containing various chemicals.

TABLE IV. THERMAL EXPANSIONS OF THE CRISTOBALITE INVESTMENT (BATCH 567) WHEN HEATED WITH VARIOUS TIME LAPSES AFTER THE BEGINNING OF MIX

TIME LAPSE AFTER MIXING	THERMAL EXPANSION (%) AT 700° C.			
	1	2	3	AVERAGE
12 min.	1.51	1.51	1.48	1.50
30 min.	1.37	1.39	1.37	1.37
1 hr.	1.31	1.31	1.32	1.31
2 hr.	1.32	1.30	1.33	1.32
3 hr.	1.29	1.27	1.25	1.27
4 hr.	1.35	1.30	1.37	1.34
6 hr.	1.33	1.33	1.34	1.33
24 hr.	1.21	1.23	1.25	1.23
48 hr.	1.24	1.23	——	1.23

Mold expansion was investigated by measuring the dimensions of castings under clinical conditions in normal casting rings. Again, time lapse between mixing and heat application varied. The means and the standard deviations of results from the groups are shown in Table V.

Variations in the setting, thermal, and total expansions of the investment and the variation in dimensional change of the resultant castings when the investment

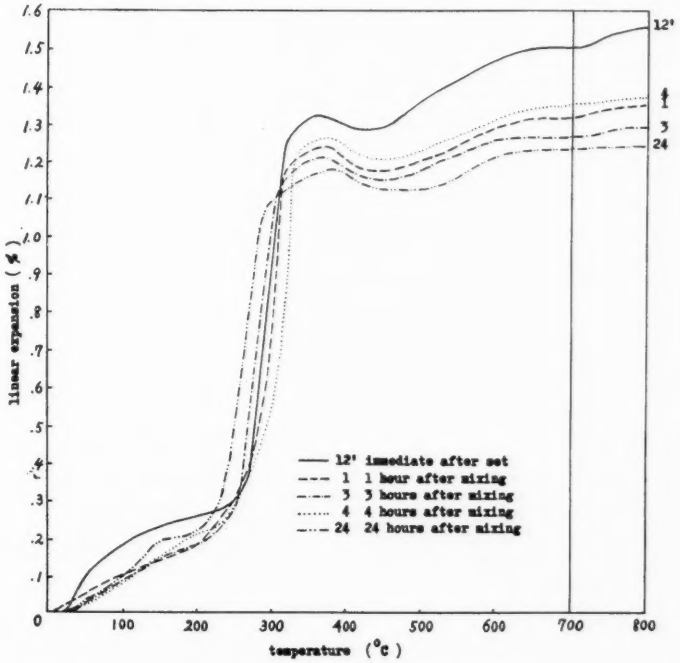


Fig. 6.—Comparison of thermal expansion curves of the investment heated with different time lapses after the beginning of mix.

was heated after different time lapses are compared by curves in Fig. 7. The thermal expansion of the investment was highest when heated immediately after the initial set. The thermal expansion decreased considerably as the time lapse increased. Such a decrease is assumed to be caused by a decrease in the setting expansion component during temperature rise.

The expansion that occurs during temperature rise is called thermal expansion. However, the expansion is a significant mixture of setting and thermal expansions if heat is applied in approximately 3 hours or less. As more time lapses between mixing and heat application, the setting expansion component contained in the apparent thermal expansion decreases; thus, the apparent thermal expansion decreases. Curve 12 (investment heated immediately after initial set) in Fig. 6 is much different from the other curves and apparently reflects a combination of setting and thermal expansion. In Fig. 7, the curves of the decrease in thermal expansion and the increase in setting expansion with varying time lapses before heating are quite inversely symmetric. The total expansion (sum of both expansions) is constant regardless of the change in time lapse up to 3 hours.

TABLE V. DIMENSIONAL CHANGES OF CASTINGS WHEN THE MOLDS WERE HEATED AT VARIOUS TIMES

TIME LAPSE BETWEEN MIXING AND HEATING	DIMENSIONAL CHANGES OF CASTING (%)
Immediately after set	−0.56 (±0.08)
1 hr.	−0.59 (±0.07)
3 hr.	−0.59 (±0.05)
4 hr.	−0.54 (±0.08)
6 hr.	−0.52 (±0.06)
24 hr.	−0.59 (±0.09)

The first evidence of thermal expansion was observed when the temperature rise began 3 hours after mixing. This time indicates when the significant setting expansion stopped. The thermal expansion increased when the time lapse increased from 3 to 4 hours, and the maximum amount of thermal expansion was still maintained after 6 hours. The reason for this increase is not clear, but the increased strength of the gypsum binder in the investment may have enhanced the cristobalite expansion.

The thermal expansion decreased again when the investment was heated 24 hours later. However, heat applied at later intervals showed no further effect. The reason for such a decrease in thermal expansion is obscure, but a possible explanation might be that the gypsum binder became strong enough to restrict the cristobalite expansion. A comparison of the curves in Fig. 6 shows that apparently the difference in thermal expansion caused by different time lapses from 3 to 24 hours originated principally at the time of the sudden expansion of cristobalite.

The total expansion of the investment (Fig. 7) was approximately constant regardless of the time the investment was heated. The expansion was highest when

the investment was heated 4 to 6 hours after mixing, but the change was less than 0.1 per cent and therefore insignificant. The curves of the dimensional change of castings invested in casting rings used in the clinic followed the same basic pattern as the curve that shows total expansion. Again, various time lapses occurred between mixing and heat application. No significant contrast was noted.

RATE OF TEMPERATURE RISE AND PROLONGED HEAT EXPOSURE

Investment thermal expansions with exposure to five different rates of temperature rise when heat was first applied 1 hour after mixing are shown in Table VI. The curves of average values from those groups are compared in Fig. 8. Rapid

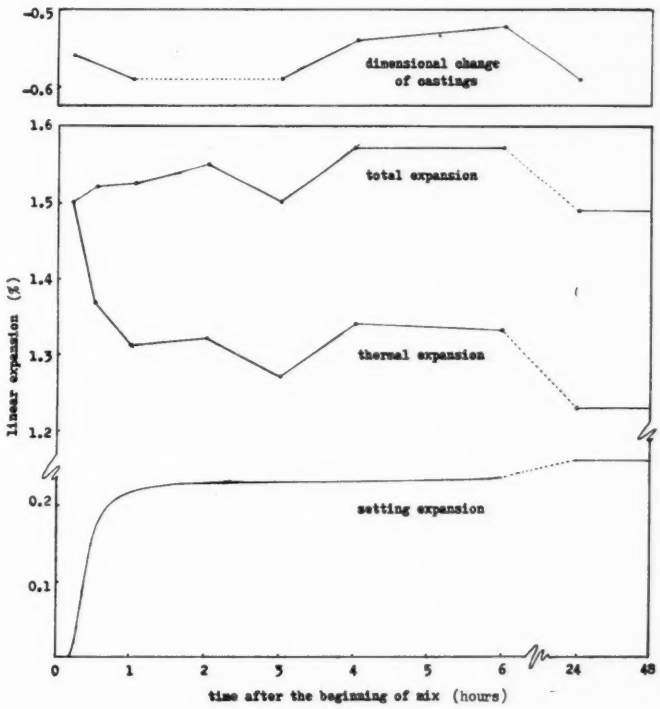


Fig. 7.—Comparison of setting, thermal, and total expansions of the cristobalite investment and the dimensional changes of castings made with that investment when heated with varying time lapse after set.

heating caused the sudden rise of the curves (characteristic of cristobalite investment) to occur at higher temperatures. Also, rapid temperature rise increased the amount of sudden expansion. However, further increase in expansion was less with rapid heating. The total amount of thermal expansion at 700° C. showed no significant difference with variation of the heating rate from 10° C. per 3 minutes to 10° C. per 30 seconds.

Two factors can account for such a result. Cristobalite expands suddenly at temperatures above 200° C. because of crystal transformation,[8] while the calcium

TABLE VI. THERMAL EXPANSION OF CRISTOBALITE INVESTMENT WITH VARYING HEATING RATE

DETERMINATION	RATE OF HEATING				
	10° C. PER 3 MIN.	10° C. PER 2 MIN.	10° C. PER 1 MIN.	10° C. PER 30 SEC.	10° C. PER 15 SEC.
Thermal expansion (%)	1.30 1.28 1.36 1.27 1.37	1.25 1.34 1.25 1.32 1.24	1.33 1.36 1.26 1.34 1.28	1.25 1.27 1.36 1.34 1.29	Cracks produced; no real expansion measured
Average	1.31	1.28	1.31	1.30	

sulfate binder continuously contracts at temperatures above 100° C. from dehydration.[9] These two effects may have occurred almost simultaneously. The transformation of cristobalite seems to require some time, so that expansion fails to keep up exactly with the rapid temperature rise. The dehydration of calcium sulfate seems to require more time. A larger amount of dehydration takes place after cristobalite transformation if investment is heated rapidly, while slow heating allows more dehydration before or during cristobalite transformation at lower temperature. Therefore, the sudden expansion is possibly inhibited because of the cristobalite change.

An unusually high expansion was observed with a rate of temperature rise of 10° C. per 15 seconds (Fig. 9). This change cannot be considered real but only

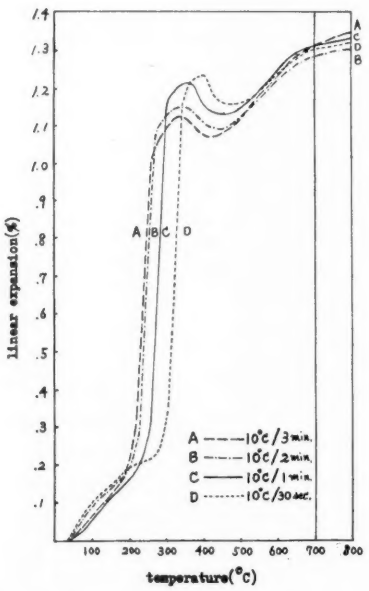


Fig. 8.—Comparison of thermal expansion of investment at different heating rates.

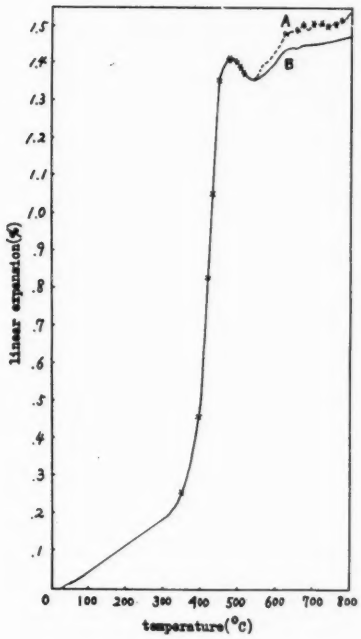


Fig. 9.—Effect of rapid heating (10° C. per 15 seconds) on thermal expansion of investment. Cross marks indicate cracking sounds.

apparent, resulting from crack formation. Actually, many cracking sounds were heard during the time of the sudden expansion and during the slight contraction phase after the expansion. Delayed cracking sounds were heard even at temperatures higher than 600° C. with some specimens. Such sounds were associated with irregular increases in apparent expansion as seen by comparison of the two curves. Thus, a heating rate of 10° C. per 15 seconds to 700° C. in 17 minutes is not advisable. A heating rate slower than 10° C. per 30 seconds (to 700° C. in 34 minutes) showed a constant thermal expansion with no cracks regardless of the

TABLE VII. EFFECT OF TIME OF KEEPING THE HEATED CRISTOBALITE INVESTMENT AT 700° C. ON EXPANSION

DETERMINATION	HEATING CONDITION		
	10° C. PER 1. MIN. TO 700° C.	THEN KEPT AT 700° C.	
		½ HR.	2 HR.
Thermal expansion (%)	1.30 1.30 1.36	1.30 1.30 1.36	1.30 1.30 1.36
Average	1.32	1.32	1.32

change in heating rate down to 10° C. per 3 minutes (to 700° C. in 204 minutes). However, the clinically tolerable limit of the rate of temperature rise should be determined by a test with an invested wax pattern, as described later.

Table VII shows the expansion of the specimens heated at 10° C. per 1 minute and maintained at 700° C. for a period of either 30 or 120 minutes. The prolonged heat exposure produced no change in thermal expansion, and no cracks were produced.

The results from the casting experiment are shown in Table VIII. Different heating rates and prolonged heating times produced no significant variation in the dimensions of resultant castings. Except for the group heated at 10° C. per 30 seconds, previous results of this section were similar to this finding.

Heating rates of 10° C. per 30 seconds seemed safe using cylindric investment blocks. However, this rate often produced fins and degrees of black staining on castings. Therefore, the dimensional changes of this group were not measured. The fins are indications of crack formation in mold walls. The cracks can be caused by the difference between the thermal expansions of the inside and outside of the investment during heating. The difference increases with larger investment blocks and with faster heating rates. The presence of molten wax or empty mold space in the blocks may also encourage crack formation.

The surfaces of castings heated at 10° C. per 30 seconds were generally stained black, especially near the sprue. The stained surfaces appeared to be slightly rough (Fig. 10). Two possible reasons can be assumed for this result. Rapid evaporation

TABLE VIII. DIMENSIONAL CHANGE AND SURFACE SMOOTHNESS OF CASTINGS WITH VARIOUS HEATING CONDITIONS

RATE OF HEATING	KEPT AT 700° C.	DIMENSIONAL CHANGE (%)	CASTING SURFACE
10° C. per 30 sec.	——	Fins formed	Rough
10° C. per 1 min.	——	0.59 (±0.07)	Smooth
10° C. per 3 min.	——	0.57 (±0.07)	Smooth
10° C. per 1 min.	2 hr.	0.56 (±0.08)	Smooth

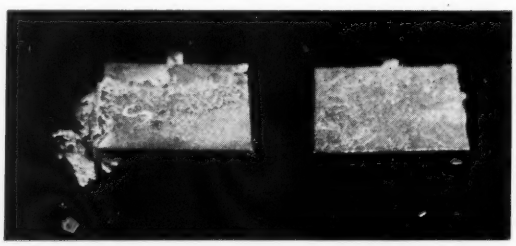
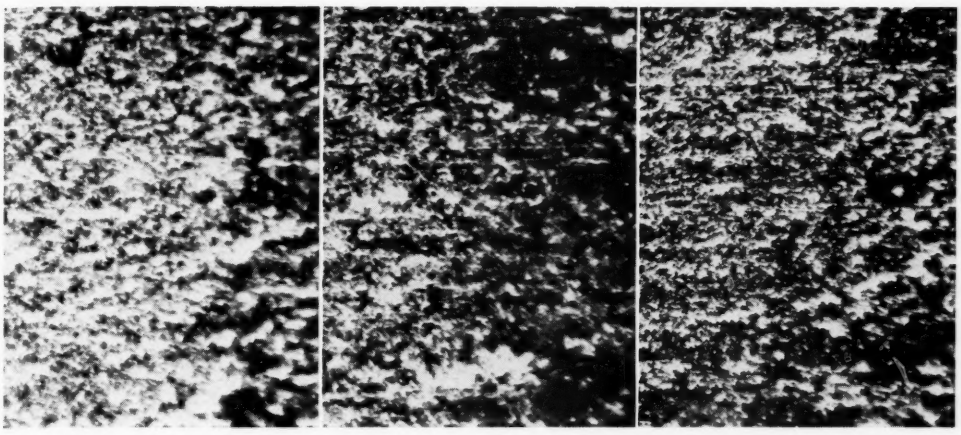


Fig. 10.—The fins and partial black staining on castings result from rapid heating at 10° C. per 30 seconds.



A. *B.* *C.*

Fig. 11.—A photomicrograph of casting surfaces (× 110; reduced 1/5). *A*, The heating rate of 10° C. per 1 minute. *B*, The heating rate of 10° C. per 3 minutes. *C*, The prolonged heat of 2 hours.

of water or wax through mold walls might roughen the surface. On the other hand, O'Brien[10] reported that the calcium sulfate binder released sulfur dioxide when heated beyond 700° C. in the presence of carbon. When the investment molds containing patterns were heated as fast as 10° C. per 30 seconds, the temperature may have reached 700° C. before the carbon from the wax could be completely burned out. Therefore, the black-stained casting surface might be due to carbon or sulfur contamination.

At any rate, an inlay casting ring of regular size should not be heated at a rate faster than 10° C. per 30 seconds to 700° C. in 34 minutes. Any heating rate slower than 10° C. per 1 minute from room temperature to 700° C. in approximately 1 hour will produce a constant expansion with an excellent casting surface and no fins even though the temperature is held at 700° C. for a long period of time (Fig. 11). Larger size casting rings probably require slower heating.

TABLE IX. HEATING AND COOLING CONDITIONS

GROUPS		HEATING	COOLING	REHEATING
Normal heating	A	Room temperature ——→ 700° C.	——→ 650° C.	——→ 700° C.
	B	Room temperature ——→ 700° C.	——→ 600° C.	——→ 700° C.
	C	Room temperature ——→ 700° C.	——→ room temperature	——→ 700° C.
Overheating	D	Room temperature ——→ 750° C.	——→ 650° C.	——→ 700° C.
	E	Room temperature ——→ 750° C.	——→ 400° C.	——→ 750° C.
	F	Room temperature ——→ 800° C.	——→ 600° C.	——→ 700° C.
	G	Room temperature ——→ 800° C.	——→ 500° C.	——→ 800° C.
	H	Room temperature ——→ 850° C.	——→ 600° C.	——→ 700° C.

UNDERHEATING OR OVERHEATING AND COOLING AND REHEATING

The thermal expansion and contraction of cylindric specimens of investment (batch 567) was measured by changing the temperature as shown in Table IX. Specimens were heated at a rate of 10° C. per 1 minute and cooled in the furnace with the electric current on.

The expansions of specimens at various temperatures are shown in Table X. Representive curves are shown in Fig. 12. The expansion curve of the cristobalite investment when originally heated was nearly horizontal between 600° C. and 800° C. as reported by many researchers.[5] Deviations of 100° C. above or below 700° C. did not significantly change the investment expansion.

The contraction curve during the cooling phase was not horizontal but fell rather quickly and evenly. Such contraction was not clinically significant (smaller than 0.07 per cent) if cooled less than 50° C. However, the contraction increased to more than 0.1 per cent if cooled more than 100° C. The dimensions were less than the original dimensions when the specimens were cooled to room temperature.

Reheating resulted in an expansion curve that followed the same pattern as the previous cooling curve. Thus, an investment which is heated and cooled before casting should be reheated to the temperature level it had reached before, even if it had been previously overheated.

Skinner[5] warned of possible crack formation caused by cooling and then reheating a quartz investment. With this cristobalite investment, no fins on the

TABLE X. THERMAL EXPANSION OF THE CRISTOBALITE INVESTMENT (BATCH 567) WHEN HEATED, COOLED, AND REHEATED

SIGN	ORIGINAL EXPANSION (%)		EXPANSION ON COOLING (%)		RE-EXPANSION (%)	
	700° C.	OVERHEATED	700° C.	COOLED	700° C.	OVERHEATED
A1	1.28		1.28	1.18 (650° C.)	1.26	
B1	1.25		1.25	1.14 (600° C.)	1.24	
2	1.26		1.26	1.17 (600° C.)	1.25	
3	1.32		1.32	1.22 (600° C.)	1.30	
C1	1.34		1.34	−0.14 (20° C.)	1.40	
2	1.24		1.24	−0.08 (21° C.)	1.30	
3	1.31		1.31	−0.07 (20° C.)	1.31	
D1	1.29	1.30 (750° C.)	1.27	1.23 (650° C.)	1.26	
E1	1.25	1.27 (750° C.)	1.21	0.78 (400° C.)	1.17	1.22 (750° C.)
2	1.22	1.25 (750° C.)	1.23	0.87 (400° C.)	1.16	1.25 (750° C.)
F1	1.25	1.29 (800° C.)	1.10	0.94 (600° C.)	1.09	
2	1.24	1.27 (800° C.)	1.19	1.08 (600° C.)	1.16	
G1	1.22	1.26 (800° C.)	1.17	0.88 (500° C.)	1.12	1.25 (800° C.)
H1	1.30	1.31 (850° C.)	1.17	1.05 (600° C.)	1.13	
2	1.25	1.29 (850° C.)	1.05	0.94 (600° C.)	1.10	

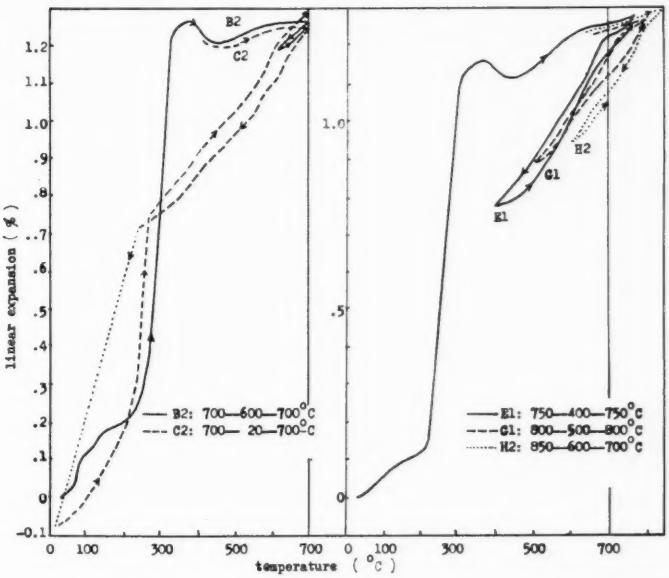


Fig. 12.—Dimensional change of the investment by heating, cooling, and reheating.

castings or cracks of molds were found when it was heated to 700° C., then cooled to room temperature, and again reheated to 700° C. before casting. The cast surfaces were not roughened by this treatment.

SUMMARY AND CONCLUSIONS

The influence of various clinical variables on the properties of a commercial cristobalite investment and castings invested with it was investigated. The following findings and conclusions were obtained.

1. Temperature changes from 18° to 28° C. or humidity changes from 60 to 80 per cent produced no significant change in setting time, setting expansion, or thermal expansion.

2. The increase of the water/powder ratio from 0.35 to 0.37 delayed the initial set by 1 minute, decreased the setting expansion by 0.06 per cent, and decreased the thermal expansion by 0.11 per cent.

3. Sodium fluoride was the most powerful restricting agent of setting expansion among tested accelerators. Addition of sodium fluoride increased the thermal expansion very little if at all and produced smooth cast surfaces. Sodium chloride, sodium sulfate, and potassium chloride considerably increased the thermal expansion; however, they roughened the cast surfaces.

4. An increase or decrease of the time between mixing and heat application showed marked effect on the thermal expansion of the investment. With heating immediately after the initial set, the thermal expansion was very high because of the continuing setting expansion. Apparent thermal expansion decreased over a period of time to the first minimum after 3 hours, slightly increased with time lapses between 4 and 6 hours, and then again slightly decreased after 1 day or more.

5. The total expansion of the investment was approximately constant regardless of the time lapse before heating. The expansion was highest when the investment was heated 4 to 6 hours after mixing. However, the change was less than 0.1 per cent and therefore insignificant.

6. Cracks in the mold walls were produced and stained, rough cast surfaces were noted when the investment mold was heated too rapidly. A slower temperature rise with regular casting rings produced a constant mold expansion and smooth cast surfaces with no cracks or stain regardless of different heating rates. Prolonged heat exposure did not change the results.

7. A deviation of 100° C. above or below 700° C. did not significantly change the expansion of the investment when heated originally.

8. The contraction curve of the investment during the cooling phase from the high temperature was not horizontal but fell rather quickly and evenly. The contraction was less than 0.07 per cent if cooling was less than 50° C., but the contraction increased to more than 0.1 per cent if the investment was cooled more than 100° C. The specimens had dimensions less than the original ones when cooled to room temperature.

9. Reheating of the cooled investment recovered the original expansion following the same pattern as the previous cooling curve. An investment mold which is cooled after heating should be reheated to the previous high temperature even if it had been overheated. Such a treatment produces neither cracks nor roughness on cast surfaces.

Drs. Akio Suzuki, Masanao Shimamura, and Norio Mitsumori, graduate students at the Tokyo Medical and Dental University, assisted in this experiment. Dr. S. Iwao, Professor of Dental Technology, and his staff gave extensive help with equipment and constructive suggestions. Dr. Daryl Beach, Professor at Nihon University Dental School, was kind enough to assist in English translation. These assistances are greatly appreciated.

REFERENCES

1. Fusayama, T.: Factors and Technique of Precision Casting, I, J. Pros. Den. **9**:468, 1959.
2. Fusayama, T.: Factors and Technique of Precision Casting, II, J. Pros. Den. **9**:486, 1959.
3. Fusayama, T.: Technical Procedure of Precision Casting, J. Pros. Den. **9**:1037, 1959.
4. Fusayama, T., Sakurai, S., and Suzuki, E.: Setting Changes of Hydrocal in Free State and in Various Hydrocolloid Impressions, Bull. Tokyo M. & D. Univ. **3**:31, 1956.
5. Skinner, E. W.: The Science of Dental Materials, ed. 4, Philadelphia, 1954, W. B. Saunders Company, pp. 32, 321, 326, 341.
6. Moore, T. E.: Method of Making Dental Castings and Composition Employed in Said Method, U. S. Patent No. 1,924,874 (Aug. 29) 1933.
7. Fusayama, T.: Dimensional, Form and Hardness Changes of Dies for Indirect Dental Technic, J.A.D.A. **52**:162, 1956.
8. Volland, R. H., and Paffenbarger, G. C.: Cast Gold Inlay Technic as Worked Out in the Cooperative Research at the National Bureau of Standards and Applied by a Group of Practicing Dentists, J.A.D.A. **19**:2, 1932.
9. Souder, W., and Paffenbarger, G. C.: Physical Properties of Dental Materials, National Bureau of Standards Circular C. 433, Washington, D. C., 1942, U. S. Government Printing Office.
10. O'Brien, W. J., and Nielsen, J. P.: Decomposition of Gypsum Investment in the Presence of Carbon, J. D. Res. **38**:541, 1959.

Tokyo Medical and Dental University
3-Chome, Yushima, Bunkyo-Ku
Tokyo, Japan

INFLUENCE OF PARTICLE SIZE OF STONE ON SURFACE DETAIL OF CASTS

RICHARD W. HENRY, D.D.S., AND RALPH W. PHILLIPS, M.S.
Indiana University, School of Dentistry, Indianapolis, Ind.

INTIMATE REPRODUCTION OF SURFACE DETAIL is a primary requisite of any impression material. Several investigations have been concerned with measurement of surface reproduction,[1,2] and a difference in the ability of various impression materials to reproduce fine surface detail was demonstrated. It was also shown that the ability of the impression material to register detail from the original die exceeds the reproduction capabilities of the cast materials which were tested. Although certain artificial stones were superior, none routinely copied the more minute detail of the impression.

It was felt that it might be possible to improve reproduction characteristics of artificial stone by reducing the particle size of the powder. Thus, the purpose of this investigation was to study the effect of stone particle size on reproduction of surface detail.

TABLE I

INDENTATIONS	LENGTH (μ)	DEPTH (μ)
1	422	28
2	307	20
3	202	12
4	109	7
5	62	4
6	45	3
7	34	2

METHODS

Six commercial elastic impression materials were used to secure the original impressions. The impression materials used were two polysulfide polymers, two silicones, and two reversible hydrocolloids. The same test dies were employed as in a previous study.[1] The dies were stainless steel cylinders on which patterns of Knoop indentations were placed. Each pattern consisted of three scales of seven indentations. The dimensions of the indentations in each row are given in Table I.

This research was supported in part by grant D-433 from the National Institute of Dental Research, U. S. Public Health Service.

TABLE II. PERCENTAGE REPRODUCTION OF EACH INDENTATION BY THE VARIOUS IMPRESSION MATERIALS (VOIDS INDICATE 100 PER CENT REPRODUCTION)

MATERIAL	RELATIVE SIZES OF INDENTATIONS						
	422μ	307μ	202μ	109μ	62μ	45μ	34μ
Permlastic							100
Coe-Flex							100
Elasticon					98	90	85
Siligel							100
Deelastic						99	93
Surgident						99	92

A minimum of 24 impressions was made with each impression material. The manufacturer's directions were carefully followed and standardized in proportioning, mixing, gelling or curing time, etc., for each material. A syringe was used to dispense all materials onto the surface of the master die to minimize air voids. The impressions were stored in a humidifier at approximately 100 per cent humidity and at 37° C. until set or gelled.

The impressions were observed under uniform lighting conditions at 163 power magnification after separation from the master die. The number of indentations reproduced in the impression was recorded.

The impression was poured within 10 minutes, using mechanical vibration. The stone was mixed under vacuum. Four different experimental materials were employed. All were class II type (densite) stones to which no accelerators or retarders had been added, because these agents would only deter from the basic problem of this research, i.e., the influence of particle size per se. The setting times of all four stones, as measured by a Gilmore needle, were within ± 1 minute of each other.

The control material was the stone as received by the dental manufacturer.* This stone was then ground in a ball mill for 1 hour, 2 hours, and 3 hours. Aliquots were removed at each interval. No attempt was made to measure the particle size or particle size distribution of each of these materials but, presumably, the grinding reduces the particle size somewhat and is a practical way of accomplishing this end.

Six casts were poured from each impression material including the control, 1 hour, 2 hour, and 3 hour grinds of stone. The poured impressions were stored

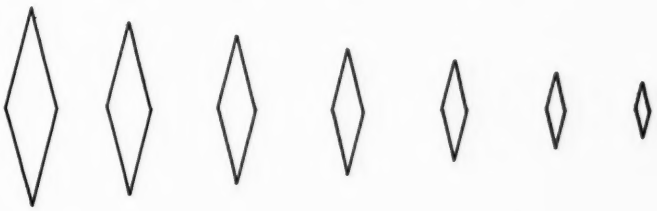
*Kerr Mfg. Co., Detroit, Mich.

in a humidifier at approximately 100 per cent humidity. The casts were separated from the impression at the end of 1 hour and then stored for a minimum of 3 days. Powdered graphite was lightly brushed onto the stone surface with a small camel's hair brush to provide a darker surface for detecting the indentations under the reflected light. The number of indentations reproduced was recorded as observed under the same magnification and lighting employed with the impression itself. In tabulating the percentage reproduction of the indentations, minor discrepancies such as voids were disregarded provided the detail was sharp and if the next smallest indentation was routinely present.

RESULTS

The average percentage reproduction for each indentation from the various impression materials is seen in Table II. These data corroborate the conclusion of the previous investigation[1] that the polysulfide rubbers, silicones, and reversible hydrocolloids are excellent in their ability to reproduce the smallest indentation. For example, three of the six materials reproduced even the 34μ long indentation 100 per cent.

TABLE III. PERCENTAGE REPRODUCTION OF THE VARIOUS INDENTATIONS IN DIFFRENT PARTICLE SIZE STONES POURED IN THE SEVERAL TYPES OF IMPRESSION MATERIALS

MATERIAL	RELATIVE SIZES OF INDENTATIONS						
	422μ	307μ	202μ	109μ	62μ	45μ	34μ
							
Polysulfide polymers							
Standard grind	100	100	100	100	75	8	0
One hour grind	100	100	100	100	97	44	0
Two hour grind	100	100	100	100	97	86	10
Three hour grind	100	100	100	100	97	88	12
Silicones							
Standard grind	100	100	100	69	30	1	0
One hour grind	100	100	100	80	35	5	0
Two hour grind	100	100	100	86	39	5	0
Three hour grind	100	100	100	97	47	6	0
Hydrocolloids							
Standard grind	97	86	80	31	2	0	0
One hour grind	94	92	85	33	5	0	0
Two hour grind	100	97	86	61	11	0	0
Three hour grind	100	100	88	61	19	3	0

Only those impressions which duplicated all of the indentations were poured in the four stones. The ability of each stone to reproduce the impressions present in the original impression materials, classified by types of impression materials, is seen in Table III. None of the stones routinely reproduced all of the indentations, but the reproduction was better as the particle size of the stone was reduced. This was particularly true for the polysulfide rubber impression materials. It appears that the interfacial relationship between the polysulfide impression material and the experimental grinds of stone is more intimate and superior than that which exists between the stones and the two other types of impression materials tested. For example, when the standard grind stone was employed, only 8 per cent of the 45μ long indentations were reproduced. However, the percentage of reproduction increased to 88 when the stone was ground for 3 hours. Using this same small particle size stone, it was even possible to reproduce the smallest indentation in 12 per cent of the casts.

TABLE IV. SUMMARY OF PERCENTAGE REPRODUCTION IN VARIOUS STONES, AVERAGING RESULTS ON ALL IMPRESSION MATERIALS

STONE	RELATIVE SIZES OF INDENTATIONS						
	422μ	307μ	202μ	109μ	62μ	45μ	34μ
Standard grind	99	95	92	70	37	5	0
One hour grind	99	97	92	71	41	15	0
Two hour grind	100	99	95	83	49	31	4
Three hour grind	100	100	96	87	55	33	5

Each succeeding grind produced superior results, with the greatest variation occurring between the 1 hour and 2 hour grinds. However, the relatively low percentage reproduction of the smallest Knoop indentation indicates that decreasing the stone particle size is only one factor to be considered in the duplication of fine detail.

Averaging the dies made from all of the impression materials, a composite of the percentage reproduction in stone from all impressions is seen in Table IV. This summary indicates that definition is improved by reducing the particle size of the stone.

CONCLUSIONS

The influence of the particle size of artificial stone upon reproduction of surface detail has been studied. Although none of the experimental products tested routinely reproduced all of the intimate detail present in the impressions, the reproducibility was improved when the particle size of the stone was reduced. However, factors other than particle size influence surface reproduction of stone casts poured in elastic impression materials.

REFERENCES

1. Ayers, H. D., Phillips, R. W., Dell, A., and Henry, R. W.: Detail Duplication Test Used to Evaluate Elastic Impression Materials, J. Pros. Den. **10**:374-380, 1960.
2. Fusayama, T., and Hosoda, H.: Surface Reproducibility of Elastic Impression Materials, Paper read at the 37th annual meeting of the International Association for Dental Research, San Francisco, Calif., March 21, 1959.

1121 West Michigan St.
Indianapolis 2, Ind.

REACTION OF SUBCUTANEOUS CONNECTIVE TISSUE OF RATS TO IMPLANTED DENTAL CEMENTS

JOHN B. BOYD, JR., D.D.S., M.S.D.,* AND DAVID F. MITCHELL, D.D.S., PH.D.
Indiana University, School of Dentistry, Indianapolis, Ind.

MOST TESTS OF THE EFFECTS of various filling materials on the pulp and gingival tissues have involved cavities in the teeth of experimental animals or man. This procedure is good, but many uncontrollable errors may be introduced, such as misinterpretation of the results because of the influence of cavity preparation. Most studies of the effects of the various means of cavity preparation on the dental pulp show that some damage is done.[1-8] It is possible that a cumulative result might be obtained when the injury caused by the filling material is superimposed. Therefore, the true pulpal reaction to filling or cementing materials is difficult to ascertain in this manner. A simple procedure, uncomplicated by cavity preparation, is needed to evaluate the irritational qualities of dental materials.

The purpose of this work was to study the connective tissue inflammatory reaction produced by the various commercial dental cements, using the procedure established by Mitchell[9] and Zawawi.[10]

METHODS AND MATERIALS

Nineteen commercially prepared cements used either for cementing purposes or as bases in deep cavity preparations were grouped according to composition as zinc phosphate, silicophosphate, polyantibiotic, acrylic resin, and copper cements (Table I). All materials were supplied in the form of a powder and a liquid.

Fifty-seven young male Wistar rats were used as subjects. Three sites were selected for implantation in each animal, two on the dorsal aspect at the shoulder and pelvic levels and one on the ventral part of the abdomen. Each material was implanted in triplicate in three animals. One animal was sacrificed for each material at each of three intervals, after 2, 16, and 32 days. These intervals were selected since earlier work by Mitchell[9] and Zawawi,[10] using implants in the subcutaneous tissue of the rat, showed that the acute reaction to the implant could be observed at 2 days, the chronic reaction at 16 days, and the reparative or chronic reaction at 32 days. Hence, three specimens of each material from one animal were available at each interval. Thus, nine specimens were selected per material, and approximately three sections of each specimen were studied microscopically.

Five animals died during the experiment and the implantation was repeated in new rats. The causes of death were not related to the materials implanted. The substitute animals survived.

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*Present address: Howard University, College of Dentistry, Washington, D. C.

The animals were anesthetized by administering pentobarbital* peritoneally at 3.5 mg. per 100 Gm. body weight. The site of implantation was shaved with electric shears. A clean, transverse incision was made with a scalpel. The skin was lifted and a blunt tweezers was inserted cephalically to permit easy access for the syringe nozzle. Then, the material to be used was mixed to a creamy consistency similar to that used in cementing gold restorations. The mix was loaded into a Kerr rubber-base syringe and injected into the tissue space previously created. The material was placed about 15 mm. cephalad to the incision. The amount of material injected varied from 0.1 to 0.3 ml. because of the difficulty of calibrating the Kerr syringe. The incision was sutured. The animals were numbered by ear punch code, caged, and maintained under uniform conditions.

Careful gross observations were made before sacrifice of the animals by subjecting them to an overdose of chloroform. The operative areas were shaved again on the sixteenth and thirty-second days, but this was not necessary with the animals which were observed only 2 days. Then, a 30 sq. mm. surface of skin and underlying connective tissue containing the implant was excised and immediately transferred to a 10 per cent solution of formalin for fixation. After fixation, the implanted materials were carefully removed, and the tissue was cut directly through the implant pocket and trimmed for embedding in paraffin. Sections were cut at 7μ, and they were stained with hematoxylin and eosin.

The inflammatory response of the host tissue to the implants was the primary consideration in the evaluation of the microscopic findings. An arbitrary classification of mild, moderate, and severe was made based on earlier work.[9,10] The factors considered in the classification were (1) the type and number of leukocytes in the tissues surrounding the implant, (2) the thickness and type of fibroplasia of the capsule surrounding the implant, and (3) the degree of vascularity of the tissue. A marked difference in the healing capacity was observed around the various materials implanted.

OBSERVATIONS

Gross Observations at the Time of Sacrifice.—Most of the implant sites at the 2 day interval appeared to be healing normally. However, each of the animals with implants of Fleck's Red Cooper Cement, S. S. White Kryptex, and Petralit presented swollen, discolored, fluctuant lesions approximately 3 by 3 cm. in diameter.

At the 16 day interval, four rats presented ulcerated, scab-covered lesions of varying sizes (Fig. 1). The materials involved were Caulk's Red Copper Cement, Petralit, Fleck's Red Copper Cement, and Ames Black Copper Cement. In addition, the rat with Caulk's Di-Cem #1 Cement presented large, open, necrotic, malodorus lesions, and the rat with Justi Resin Cement presented a large, swollen, necrotic lesion at the pelvic site. The implant sites in the other animals sacrificed at this time were essentially negative.

At the end of the 32 day period, five rats showed evidence of large unhealed lesions associated with slough of the implants and deep scarring (Caulk's Di-Cem

*Nembutal.

TABLE I. COMPOSITION AND REACTION OF IMPLANTS IN INCREASING ORDER OF SEVERITY

MATERIALS	MANUFACTURER	INGREDIENTS*	INTERVAL (DAYS)	REACTION
Group I. Zinc Phosphate Cements				
Stratford-Cookson	Stratford-Cookson Co.	ZnO MgO 10/1	2	Mild
			16	Mild
			32	Mild
S. S. White Zinc Cement	The S. S. White Dental Mfg. Co.	ZnO MgO	2	Moderate
			16	Mild
			32	Moderate
Caulk's Tenacin Cement	L. D. Caulk Co.	ZnO 90% MgO 10%	2	Moderate
			16	Mild
			32	Moderate
Lang's C & B Cement	Lang Dental Mfg. Co.	ZnO 92% Mg (OH) 6% Bi_2O_3 2%	2	Severe
			16	Moderate
			32	Moderate
S. S. White Silver Cement	The S. S. White Dental Mfg. Co.	ZnO MgO Ag 2%	2	Severe
			16	Moderate
			32	Moderate
Ames Z-M Cement	The W. V. B. Ames Co.	ZnO 85-90% MgO Bi_2O_3 silica	2	Severe
			16	Moderate
			32	Severe
Group IV. Acrylic Resin				
Caulk's Grip Cement	L. D. Caulk Co.	Methyl methacrylate Vinyl copolymer Heavy filler 65% Peroxide catalyst	2	Moderate
			16	Mild
			32	Mild
Justi Resin Cement	H. D. Justi and Son, Inc.	?	2	Severe
			16	Mild
			32	Mild
Amco Lifetime Cement	American Consolidated Mfg. Co.	Resin Adhesive Inert filler Accelerator Color stabilizer	2	Moderate
			16	Moderate
			32	Moderate
Smith's Resin Cement	The William Getz Corporation	?	2	Severe
			16	Severe
			32	Mild
Group V. Copper Cements				

Group V. Copper Cements				
Caulk's White Copper Cement	L. D. Caulk Co.	Tenacin cement plus copper iodide	2	Moderate
			16	Moderate
			32	Moderate
Caulk's Red Copper Cement	L. D. Caulk Co.	Tenacin cement plus copper iodide, copper oxide, and pigments	2	Severe
			16	Severe
			32	Moderate
Caulk's Black Copper Cement	L. D. Caulk Co.	Tenacin cement plus copper iodide, copper oxide, and pigments	2	Severe
			16	Severe
			32	Severe
Fleck's Red Copper Cement	Mizzy, Inc.	?	2	Severe
			16	Severe
			32	Severe
Ames Black Copper Cement	W. V. B. Ames Co.	Zinc phosphate cement plus cuprous oxide and metallic copper	2	Severe
			16	Severe
			32	Severe
Group III. Polyantibiotic Cement				
A.B.C.Polyantibiotic Cement	Oskar Schaefer Mfg. Co., Inc.	Dihydrostreptomycin sulfate equivalent to 1 mg. dihydrostreptomycin base per 1 Gm.	2	Severe
			16	Severe
			32	Severe
		Chlortetracycline hydrochloride 1 mg. per 1 Gm. powder		
		Chloramphenicol 1 mg. per 1 Gm. powder		
		Bacitracin 50 units per 1 Gm. powder		
		Dental cement 22 Gm.		
Group II. Silicophosphate Cements				
Caulk's Di-Cem #1 Cement	L. D. Caulk Co.	SiO_2 34.1%	2	Severe
		Al_2O_3 26.5%	16	Severe
		CaO 7.5%	32	Severe
		Na_2O 6.9%		
		ZnO 10.2%		
		MgO 1.1%		
		F_2 8.5%		
		P_2O_5 5.9%		
S. S. White Kryptex	The S. S. White Dental Mfg. Co.	Zinc cement 80%	2	Severe
		Silicate cement 20%	16	Severe
			32	Severe
Petralit	Premier Dental Products Co.	Zinc oxide	2	Severe
		Magnesium carbonate	16	Severe
		Silica	32	Severe
		Aluminum oxide		
		Fluoride fluxes		

*The ingredients and percentage compositions were obtained from labels of the bottles or from direct communication, by letter, with the manufacturing companies. Where there is a lack of ingredients or percentages, these were not given on the label and the company declined to reveal them to the authors.

#1 Cement, Caulk's Red Copper Cement, Fleck's Red Copper Cement, Ames Black Copper Cement, and Petralit). These gross observations were in agreement with the microscopic findings.

Microscopic Observations.—The interpretation of the microscopic findings is presented in Table I. The varied tissue reactions are seen in Figs. 2 through 4.

DISCUSSION

Earlier investigators who studied the dental pulps of experimental animals or human beings reported mild to moderate reactions to zinc phosphate cements.[2,9,11,15] As a group, in this study these cements produced a mild to moderate reaction depending upon the brand used. The variation in response to the different cements of

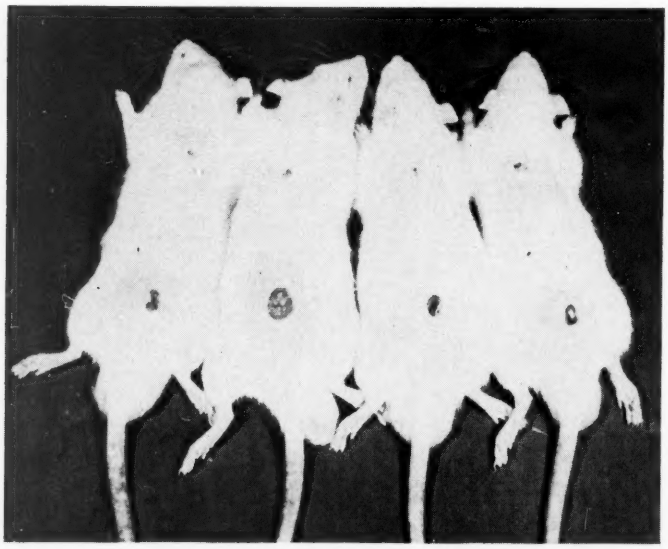
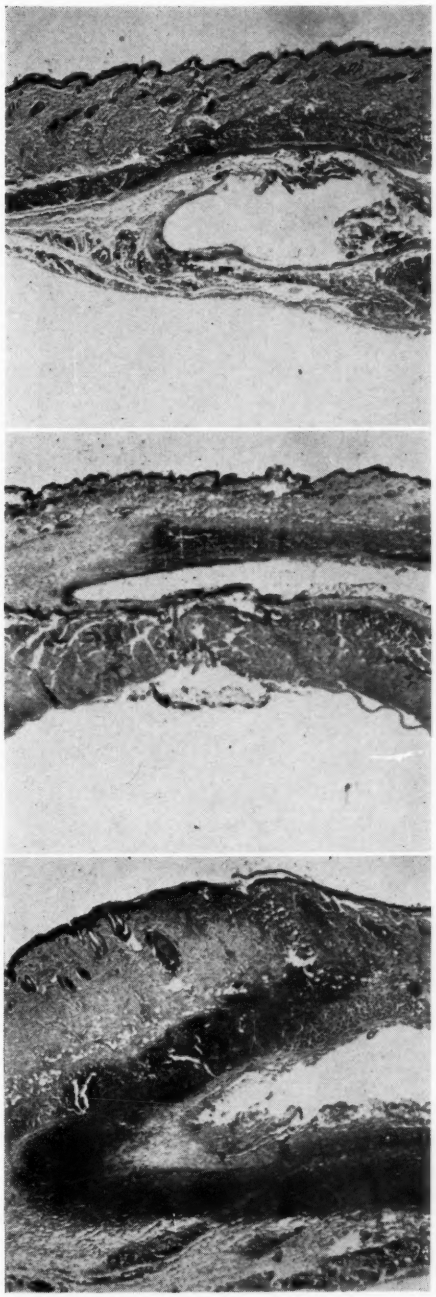


Fig. 1.—Four rats at the end of the 16 day experimental period. Lesions are in the shoulder and pelvic sites. The rats, from left to right, were implanted with Caulk's Red Copper Cement, Petralit, Fleck's Red Copper Cement, and Ames Black Copper Cement.

this basic nature seems to be due to the presence of additives such as copper, silver, silicate, or antibiotics. The zinc phosphate cements with the higher zinc oxide compositions, and conversely the lower magnesium oxide content, elicited a milder response. It is assumed that the powder composition is the influencing factor, because all of the liquids had basically the same composition (phosphoric acid).

Langeland,[16] using Caulk's Grip Cement, Smith's Resin Cement, and Justi Resin Cement in the teeth of children, reported a severe, irreversible reaction. It was our observation using the same materials that at the 2 day interval, the reaction was moderate to severe, but as the time increased, the reaction became milder. At the end of the 32 day experimental period, the material was totally innocuous.



A.

B.

C.

Fig. 2.—*A*, A mild connective tissue response is present at the end of the 2 day experimental period around Stratford-Cookson zinc phosphate cement. *B*, A moderate connective tissue response is present at the end of the 2 day experimental period around Caulk's Tenacin Cement. *C*, A severe connective tissue response is present at the end of the 2 day experimental period around Fleck's Red Copper Cement.

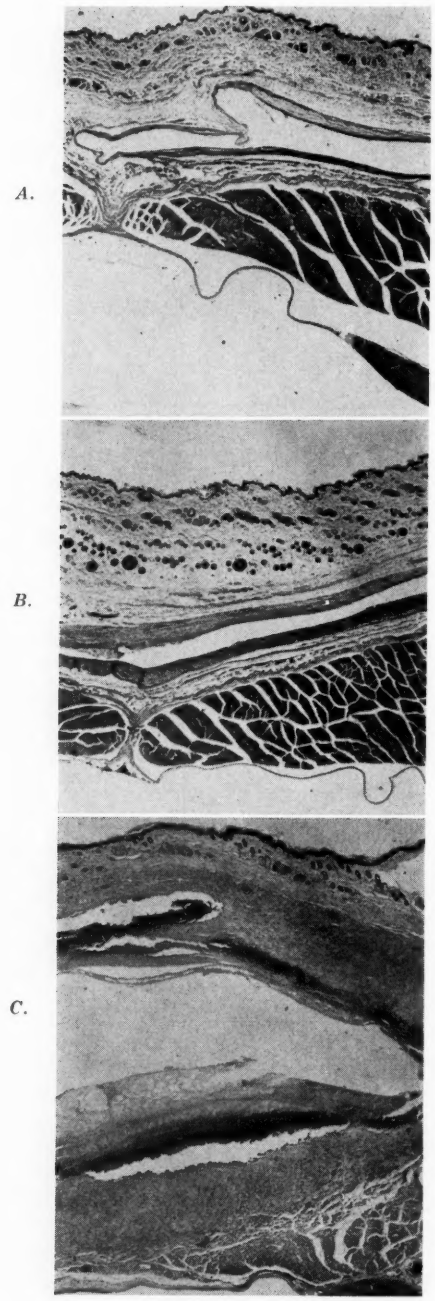
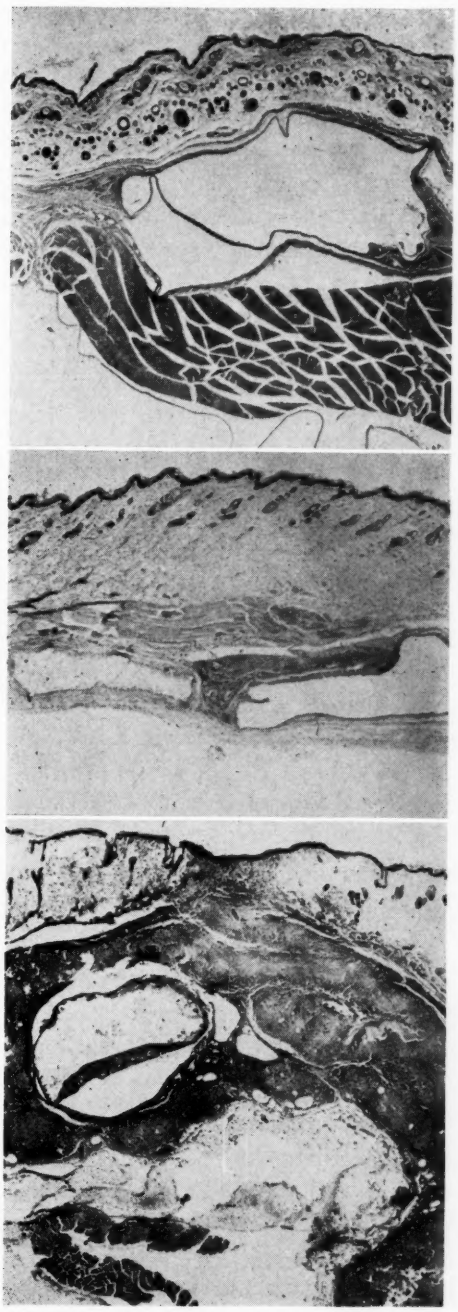


Fig. 3.—*A*, A mild connective tissue response is present at the end of the 16 day experimental period around Justi Resin Cement. *B*, A moderate connective tissue response is present at the end of the 16 day experimental period around Amco Lifetime Cement. *C*, A severe connective tissue response is present at the end of the 16 day experimental period around Smith's Resin Cement.



A.

B.

C.

Fig. 4.—*A*, A mild connective tissue response is present at the end of the 32 day experimental period around Caulk's Grip Cement. *B*, A moderate connective tissue response is present at the end of the 32 day experimental period around Caulk's White Copper Cement. *C*, A severe connective tissue response is present at the end of the 32 day experimental period around Caulk's Di-Cem #1 Cement.

The most severe reactions of the pulp reported by all previous investigators have been attributed to the copper cement group.[1,2,11,12,14,19,20] In our study, all of the copper cements tested with the exception of Caulk's White Copper Cement produced a severe reaction at all intervals. The latter produced a moderate reaction at the 2 and 16 day intervals and a severe reaction at the end of the 32 day period.

The correlations are of significance even though the earlier studies were carried out on dental pulps and this experiment was done using the subcutaneous connective tissue. Zawawi[10] states, "The connective tissue system is interconnected throughout the animal body and is formed of similar elements, cells, collagen, elastic and reticular fibers, and ground substances, hence, maintaining an overall comparable identity."

It would seem advisable, all other characteristics such as physical properties being comparable, to choose those cements with the least irritating qualities. Five cements gave mild or moderate inflammatory reactions. Seven cements caused moderate or severe reactions, and seven cements produced uniformly severe reactions.

SUMMARY AND CONCLUSIONS

Nineteen dental cements were implanted in the subcutaneous connective tissue of fifty-seven young adult Wistar rats. The cements, listed in approximate increasing order of severity of response, were Stratford-Cookson, Caulk's Grip, S. S. White Zinc, Caulk's Tenacin, Justi Resin, Amco Lifetime, Caulk's White Copper, S. S. White Silver, Lang's C & B, Smith's Resin, Caulk's Red Copper, Ames Z-M, Caulk's Black Copper, Fleck's Red Copper, Ames Black Copper, A.B.C. Polyantibiotic, Caulk's Di-Cem #1, S. S. White Kryptex, and Petralit.

From the results of this study, the following conclusions were drawn:

1. The zinc phosphate cements as a group produced a mild to moderate connective tissue response.

2. When the zinc phosphate cements had additions of silver, copper salts, antibiotics, or silicate cements, a severe connective tissue response was elicited.

3. The zinc phosphate cements with the higher zinc oxide content produced the milder connective tissue response.

4. The acrylic resin cements produced a moderate to severe connective tissue response at the end of the 2 day experimental period but produced mild to moderate responses at 16 days and 32 days, with the mild response predominating.

5. Certain correlations could be detected between the results obtained in the subcutaneous connective tissue of the rat and earlier results obtained by other investigators using similar materials in the teeth of human beings and experimental animals.

6. The subcutaneous connective tissue of rats can be used as an initial mass screening medium to bioassay the reactions of vital tissues to dental materials used in teeth or in or on the gingivae.

7. Further study along these lines with other dental materials is warranted.

REFERENCES

1. Fish, E. W.: The Reaction of Dental Pulp to Peripheral Injury of the Dentin, Brit. D. J. **52**:338, 1931.
2. Silberkweit, M., Massler, M., Schour, I., and Weinmann, J. P.: Effects of Filling Materials on the Pulp of the Rat Incisor, J. D. Res. **34**:854, 1955.
3. James, V. E., Schour, I., and Spence, J. M.: Response of Human Pulp to Gutta-percha and Cavity Preparation, J.A.D.A. **49**:639, 1954.
4. Zach, L., and Brown, G. N.: Pulpal Effect of Ultrasonic Cavity Preparation. Preliminary Report, New York D. J. **22**:9, 1956.
5. Healey, H. J., Patterson, S. S., and Van Huysen, G.: Pulp Reaction to Ultrasonic Cavity Preparation, U. S. Armed Forces M. J. **7**:685, 1956.
6. Mitchell, D. F., and Jensen, J. R.: Preliminary Report on the Reaction of the Dental Pulp to Cavity Preparation Using An Ultrasonic Device, J.A.D.A. **55**:57, 1957.
7. Kennedy, J. J., Buckman, N., and Proffit, W. R.: Biological Response to High Speed Instruments, J.A.D.A. **58**:35, 1959.
8. Swerdlow, H., and Stanley, H. R., Jr.: Reaction of the Human Dental Pulp to Cavity Preparation. I. Effect of Water Spray at 20,000 R.P.M., J.A.D.A. **56**:317, 1958.
9. Mitchell, D. F.: The Irritational Qualities of Dental Materials, J.A.D.A. **59**:954, 1959.
10. Zawawi, H. A. M.: Rat Connective Tissue Reaction to Implants of Certain Pulp Capping and Cavity Lining Materials, Thesis, Indiana University, School of Dentistry, 1958.
11. Gurley, W. B., and Van Huysen, G.: Histologic Response of Teeth of Dogs to Operative Procedures, J. D. Res. **19**:179, 1940.
12. Gurley, W. B., and Van Huysen, G.: Histologic Changes in Teeth Due to Plastic Filling Materials, J.A.D.A. **24**:1807, 1937.
13. Ringland, P.: Zinc Phosphate Cement, J. Den. Children **13**:24, 1946.
14. Crowell, W. S.: Physical Chemistry of Dental Cements, J.A.D.A. **14**:1030, 1927.
15. Zanders, H. A., and Pejko, I.: Protection of the Pulp Under Silicate Cements With Cavity Varnishes and Cement Fillings, J.A.D.A. **34**:811, 1947.
16. Langeland, K.: Pulp Reactions to Resin Cements, Acta odont. scandinav. **13**:239, 1956.
17. Massler, M.: Effects of Filling Materials on the Pulp, J. Tennessee D. A. **35**:353-374, 1955.
18. Massler, M.: Effects of Filling Materials on the Pulp, New York J. Den. **26**:183, 1956.
19. Dixon, R. A.: Histopathological Changes in Pulp and Dentin Under Different Filling Materials, J. Am. Col. Den. **1**:57, 1934. (Abst.)
20. Manley, E. B.: Pulp Reaction to Dental Cements, D. Rec. **64**:75, 1944.

HOWARD UNIVERSITY
COLLEGE OF DENTISTRY
600 W ST., N.W.
WASHINGTON 1, D. C.

CLEFT PALATE PROSTHESIS

CONGENITAL CLEFT LIP AND PALATE TREATMENT PLAN

OSCAR E. BEDER, B.S., D.D.S.*
University of Washington, School of Dentistry, Seattle, Wash.

THE PROSTHODONTIC PHASE of a team effort of habilitation of persons with congenital cleft lip and palate encompasses total study and planning. Even after the closest scrutiny, unforeseen contingencies may occur. A procedure must be used that is cognizant of as many factors as possible and that is amenable to correction during the course of treatment.

The comprehensive approach to therapy should be initiated. An evaluation is attempted wherein the dentist measures the attitudes of acceptance or rejection of the individual by members of society. The environment is studied relative to home, school, and play. The atmosphere at the place of employment and social area are reviewed for adults. The motivation of the individual as to attitudes, basic needs, and desires is determined, since motivation may give an immediate clue to the complexity of collateral aspects of the problem. If indicated, the services of a psychologist or social worker should be employed. Any opinions of genetic or possible environmental predisposition should be noted for future statistical analysis.

PATIENT EXAMINATION

An objective and subjective examination of the patient is made. The following items are noted.

Lip.—(1) Cleft, if present, (2) degree of cleft, (3) location of cleft, (4) lip surgical correction, if accomplished, (5) contour of the lip—anterior and profile view, and (6) whether the lip is adequate or tight.

Palate.—(1) Cleft, if present, (2) degree of cleft (classification), (3) condition of premaxilla, (4) whether the cleft has been treated surgically, (5) length of soft palate, (6) mobility of soft palate, and (7) features, such as scarring, postsurgical clefts, tightness, asymmetry, neurologic involvement, vault contour, etc.

Oronasopharynx.—(1) Posterior wall movement, location of the prominence of the first cervical vertebra, Passavant's pad, features such as encrustation, and adenoid tissue and (2) lateral wall movement and features such as patency of the orifice of the Eustachian tube.

*Professor of Prosthodontics, Director of Maxillofacial Prosthesis Clinic, Dental School, and Director of Dental Service, Children's Orthopedic Hospital, Seattle, Wash.

Pillars.—(1) Anterior movement and features, (2) tonsil—present, absent, regeneration, and (3) posterior pillars—movement and features.

Velopharyngeal Sphincter.—(1) Competent or incompetent, (2) degree of competency, and (3) presence of a tonsillar ring.

Dentition.—(1) Occlusion and dental arch relationship and curve of Spee, (2) midsagittal plane relation of anterior teeth, (3) vertical dimension and interocclusal distance, (4) caries, (5) missing teeth, and (6) incomplete eruption.

A medical history should be available to determine the relation of previous procedures in surgery, otolaryngology, associated congenital anomalies, and other pertinent data, such as previous speech evaluation and therapy. Intraoral study casts and, if indicated, extraoral records should be obtained. Intraoral, occlusal, and cephalometric roentgenograms and intraoral and extraoral photographs are made.

MOUTH PREPARATION PLAN

When the data obtained thus far are studied and analyzed, the dentist should give the patient or the parents a conservative but optimistic explanation of the function of the restoration. Then, the procedural routine is evaluated. The first is mouth preparation. The premaxilla is studied relative to position, size, mobility, and status of the teeth. The suture areas are carefully examined for a hiatus or oronasal fistula. If indicated, the patient is referred to a surgeon for extraction of useless teeth, improvement of the position and size of the premaxilla, and closure of the hiatus and/or fistula in the edentulous patient. The abutment teeth are analyzed for potentialities of retention and stabilization. The need for changes in contour, axial relationship, clinical crown length and width, and interocclusal dimensions for rest areas are noted. The occlusion and vertical dimension are evaluated in centric relation and centric occlusion. Degrees of malocclusion and the interocclusal distance as related to the vertical dimension of occlusion are noted.

IMPRESSION PLAN

The impression technique is visualized. The type of tray and impression material are selected to suit the conditions of the mouth. Provisions are made to preclude the development of contingencies. For example, the trapping of impression material in the nasal cavity through a small defect in the hard palate should be prevented by temporary obturation with cotton or modeling compound.

FRAMEWORK DESIGN

Some of the factors considered in the framework design are intra-arch and interarch space, need for a lip plumper or postorthodontic retainer plate, contour of the palatal vault, number of missing teeth, and the need for a palatovelar connector. The palatovelar connector follows the contour of the soft palate at rest, in most instances, and is fabricated of metal or plastic. The connector incorporates the means of adding the velar portion at its free end in the form of a loop or band.

The velar portion must be designed so that the patient can breathe through the nose. This portion may be temporarily partial or complete, depending on the

tolerance of the patient. The obturation should be complete only in function unless the movement of the posterior and lateral pharyngeal wall is so limited that a patency must be incorporated in it. The obturation should be checked subjectively and with cephalometric roentgenograms using a radiopaque material on the pharyngeal wall and the bulb to facilitate identification of the sphincteral action and possible sources of cul-de-sac resonance.

POSTCOMPLETION PLAN

After the prosthesis has been completed and adjusted, the patient should be examined by a speech therapist. The speech as affected by the restoration and the related neuromuscular pattern is evaluated, and adjustments or modifications may be suggested by the therapist. An audiometric examination may also be advisable.

A recall schedule is established for the patient. The intervals between appointments vary depending on such factors as growth, tooth eruption, tooth coverage, design of retainers, and oral hygiene. However, the patient should be seen a minimum of twice a year.

At the recall appointment, the clasps are examined for intactness and retention. The stabilizing portions should be functioning correctly. If orthodontic bands with spurs are being used for auxiliary retention, their fit and cement seal should be checked. The denture base should have good tissue adaptation, be free of cracks or roughnesses, and should be clean. The velar bulb may require modification in areas of impingement or rubbing. Artificial tooth length and/or width may be changed as the patient grows older.

Subsequent surgical intervention, in the form of uranoplasty, staphylopharyngorrhaphy, rhinoplasty, or cheiloplasty, may make it necessary to modify or eliminate the labial or buccal flange, a hard palate obturator, the connector, or the velar bulb. The design of the denture may require revision because of growth and dental problems. The latter includes tooth loss from caries or exfoliation, tooth migration, postorthodontic edentulous spaces, formation of hyperplastic tissue, and bone resorption. Tooth eruption also makes it necessary to modify the denture.

Examination of the patient at recall periods may reveal the need for speech therapy, orthodontics, restorative dentistry, dental hygiene, periodontics, or oral surgery. This situation can be resolved expeditiously if prosthodontics is a member of a cleft lip and palate habilitation team. The patient can be referred immediately to an associate who has all records, histories, study casts, roentgenograms, etc., readily accessible. The ability to consult, evaluate, debate, and even criticize is enhanced in a group of this kind.

SUMMARY

The prosthodontic treatment plan is one phase of a team effort that is comprehensive and long range in scope. An attempt is made to correlate all information related to the patient's problem in order to arrive at the best solution. Treatment is based on the premise that the burden of responsibility for therapy may shift to other disciplines at any time.

University of Washington
School of Dentistry
Seattle 5, Wash.

PROSTHETIC TREATMENT OF CLOSED VERTICAL DIMENSION IN THE CLEFT PALATE PATIENT

MOHAMMAD MAZAHERI, D.D.S., M.Sc.*
Lancaster, Pa.

OVERCLOSURE OF THE VERTICAL DIMENSION of occlusion and lack of maxillo-mandibular occlusal contact in the cleft palate patient can be related to the following abnormalities: (1) partial eruption of the deciduous and permanent teeth, (2) failure of normal vertical and lateral growth and development of the maxillae, (3) generalized disturbances of the growth pattern resulting from the cleft palate anomaly, (4) displacement or damage to the tooth bud and supporting bone during surgical procedure on the palate, (5) subsequent scar tissue formation and disturbance of blood supply to the tissue, and (6) impacted, supernumerary, malposed, and ankylosed teeth.

DESCRIPTION OF THE PROBLEM

Lack of lateral and vertical growth of the maxillae and partial eruption of the deciduous and permanent teeth are often seen in patients with congenital cleft palate. These patients frequently have congenitally missing, impacted, badly decalcified, or decayed maxillary teeth (Fig. 1). The maxillary arch is often constricted. Maxillary and mandibular teeth do not contact when the mandible is in

*Chief, Dental Services, Lancaster Cleft Palate Clinic.

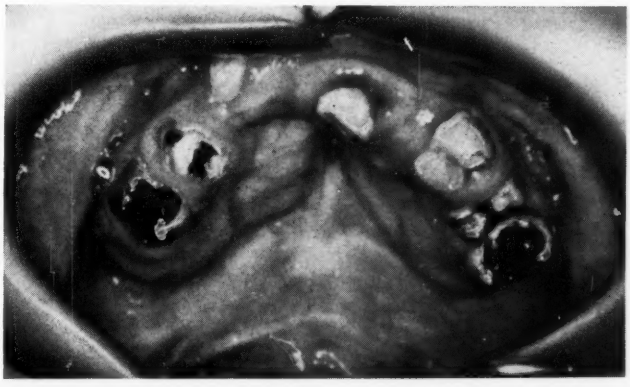


Fig. 1.—An 18-year-old girl has a postoperative unilateral cleft lip and cleft palate. Some scar tissue remains in the hard and soft palate. Cineradiography studies indicate that velopharyngeal closure is present. The remaining maxillary teeth are decalcified, partially erupted, and decayed.

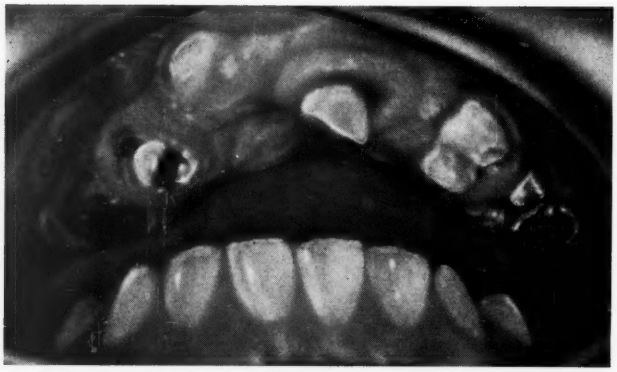


Fig. 2.—The maxillary and mandibular teeth do not contact when the patient's mouth is closed in centric occlusion. Note the excessive lateral growth of the tongue.

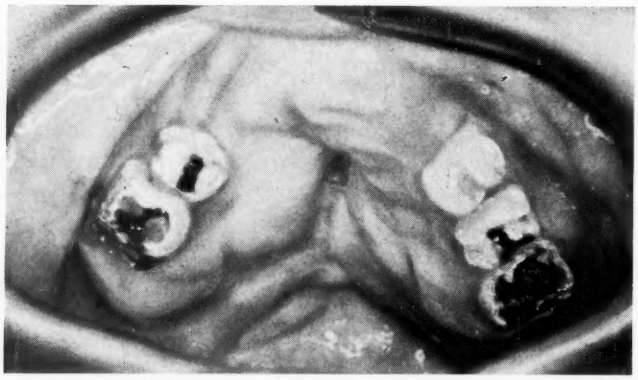


Fig. 3.—The upper left central incisor and upper right supernumerary tooth are removed and a gingivectomy has been performed.

Fig. 4.—The copings are cemented in position.

centric occlusion (Fig. 2). The upper and lower teeth are widely separated when the mandible is at physiologic rest position. The gingival sulcus is deepened because of partially erupted teeth.

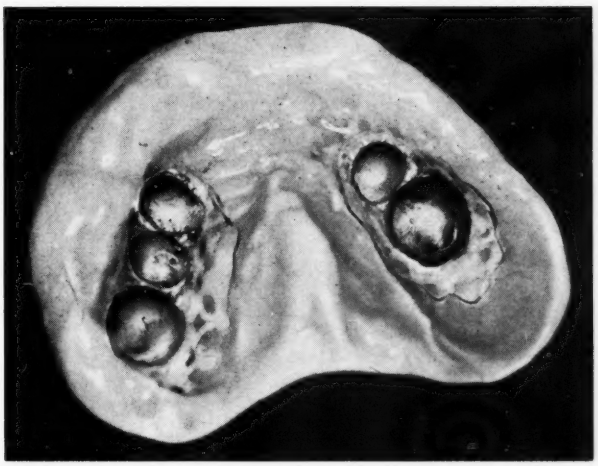


Fig. 5.—The tissue surface of the prosthesis. The cast gold thimbles are held in the resin base by the lateral extensions on the casting.

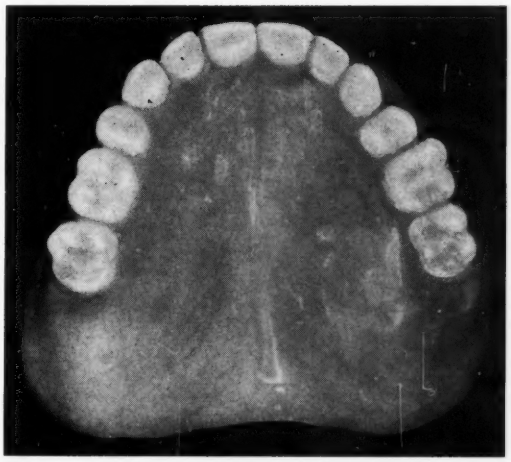


Fig. 6.—The denture is completed.

CLINICAL EVALUATION

In cleft palate patients, a prosthesis that is supported by natural teeth achieves a most satisfactory result with less damaging effects upon the supporting tissues. We have treated a number of patients with complete dentures constructed over the natural teeth. This type of prosthesis not only diminishes the occlusal load upon the

mucoperiosteum and supporting bone but also has a splinting effect upon the remaining teeth. The results are encouraging, and the periodic posttreatment examinations have shown little or no tissue changes.

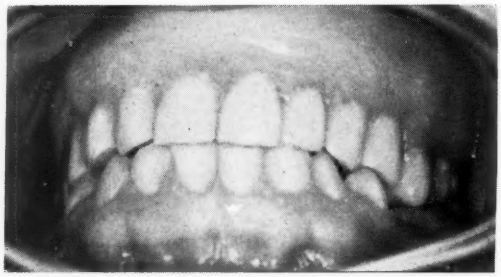


Fig. 7.—The mouth is closed in centric occlusion with the prosthesis in position.

TREATMENT

Gingivectomy is often indicated to expose more clinical crown (Fig. 3). After the complete recuperation of the gingival tissue, all remaining teeth are prepared to receive copings. Shoulderless preparations are used. The multiple impression technique is employed. Because of the excessive amount of interocclusal distance the jaw relations are not established at this stage.

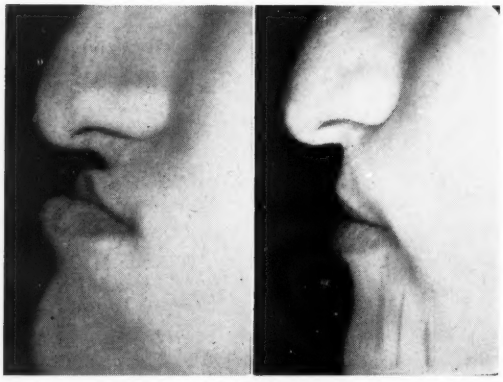


Fig. 8 Fig. 9

Fig. 8.—The prosthesis is not in the mouth.
Fig. 9.—The prosthesis is in position in the mouth.

The abutments are waxed, and the wax patterns are surveyed for the path of insertion and undercuts. The patterns are made parallel and all the undercuts are removed. The wax patterns are cast, and the copings are cemented into position (Fig. 4).

A preliminary impression is made, and an acrylic resin tray is made over the preliminary cast using one sheet of wax for relief. The resin tray is tried in the mouth and adjusted. Adaptol is used for border modification. The maxillary tissue and teeth are cleaned of saliva, and the final impression is made in a rubber-base impression material. The impression is boxed and poured in artificial stone.

An occlusion rim is made over the resin base. The vertical dimension of occlusion and centric relation are established in the same manner as if the patient were completely edentulous.

The master cast is duplicated and the abutments are covered with 16 gauge wax. The wax patterns extend 5 mm. laterally beyond the gingival margins around the abutments (Fig. 5) for fixation of the thimbles to the resin base of the denture. The wax patterns are invested and cast in hard gold. The inner surfaces of the thimbles are well polished.

The artificial teeth are arranged over the thimbles. After approval of the try-in, the denture is flasked and the wax is boiled out. The thimbles are cemented to the abutments of the cast to prevent the seepage of acrylic resin into the thimbles during packing of the denture. The denture is processed in the usual manner, polished, and inserted in the mouth (Figs. 6 through 9). When a speech bulb is indicated, the patient must be completely adjusted to the anterior part of the restoration before the "tailpiece" is added to the denture. The impression for the speech bulb is made after the patient has become accustomed to the tailpiece.

We do not insist on obtaining an accurate impression for the preliminary speech bulb. An accurate impression is made after the patient's pharyngeal tissue has become accustomed to the temporary speech bulb. The tailpiece and the preliminary bulb are constructed from self-curing acrylic resin. The tailpiece and speech bulb are not cured with heat-curing resin until an accurate impression for the speech bulb is made.[1]

SUMMARY

Lack of lateral and vertical growth of the maxillae and overclosure of vertical dimension are often seen in cleft palate patients. Complete dentures supported by natural teeth are the ideal treatment for these patients.

Copings of the remaining teeth are made to prevent decalcification and caries. The abutments are utilized only to support the prosthesis, not for retention.

The prosthetic speech restoration is constructed in three stages, each stage requiring a functional impression. An accurate functional impression of the speech bulb is obtained after the patient has adjusted to the temporary speech bulb. Heat curing of the restoration should be minimized.

REFERENCE

1. Cooper, H. K., Long, R. E., Cooper, J. A., Mazaheri, M., and Millard, R. T.: Psychological, Orthodontic, and Prosthetic Approaches in Rehabilitation of Cleft Palate Patient, D. Clin. N. America, pp. 381-393, 1960.

LANCASTER CLEFT PALATE CLINIC
24-26 NORTH LIME ST.
LANCASTER, PA.

READERS' ROUND TABLE

BIRMINGHAM, ALA.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

In the September-October, 1960, issue of THE JOURNAL OF PROSTHETIC DENTISTRY, (10: 921-926), Dr. George H. Moulton discusses "The Importance of Centric Occlusion in Diagnosis and Treatment Planning." In this article, he defines centric occlusion as being "the initial point of contact of teeth during a mandibular closure into the terminal hinge position. . . ." This definition conflicts with that given in the *Glossary of Prosthodontic Terms*, which defines centric occlusion as "the relation of opposing occlusal surfaces which provides the maximum planned contact and/or intercuspation."

There is little diagreement among prosthodontists that it is desirable that "centric occlusion" (as defined in the *Glossary*) coincide with centric relation of the mandible to the maxillae. Although this may not be true or obtainable with natural dentitions, it is a primary objective with artificial dentures.

While the definition used by Dr. Moulton might be improved, I think it is a more logical interpretation of the occlusion (the coming together of opposing tooth surfaces) that relates to the meaning of the word "centric" as used in dentistry. As Dr. Moulton points out, centric occlusion (as defined in the *Glossary*) may be an eccentric occlusion, the result of the mandible shifting into an accommodative position. The word "centric," when applied to an eccentric occlusion, is ambiguous and is therefore inappropriate. I would like to suggest that the Nomenclature Committee of the Academy of Denture Prosthetics, having assumed the responsibility of standardizing prosthodontic nomenclature, reconsider the older definition of "centric occlusion" and give favorable consideration to a definition which more closely relates to the occlusion found at centric jaw relation.

Sincerely,

WILLIAM L. MCCRACKEN, D.D.S., M.S.

The two letters printed below are presented in an effort to locate the dentist who made the complete upper denture that is the only clue to the identity of a skeleton found last September in Montana. It is hoped that if the work is recognized, the dentist will be able to provide the local coroner with the name of the patient and his address.

SEPTEMBER 30, 1960

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

DEAR SIR:

On September 14, 1960, a skeleton was found in the mountains southeast of Butte. After a complete search of the area for forms of identification, the only possibility we found was the skeleton's denture. I am enclosing a description of the denture written by the Butte Dental Arts Laboratories.

They advised me to write to your journal and that you would be courteous enough to print an article that may help in the identification of the skeleton.

Your courtesy and kindness will be appreciated.

Yours very truly,

ANDY ALEKSICH
SILVER BOW COUNTY CORONER
BUTTE, MONTANA

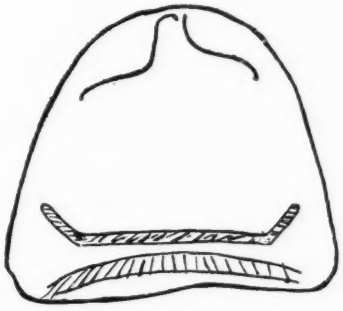
(Below are the description and sketch of the denture provided by the laboratories.)

SEPTEMBER 23, 1960

MR. ANDY ALEKSICH, CORONER
SILVER BOW COUNTY
BUTTE, MONTANA

DEAR MR. ALEKSICH:

The denture was of Lucitone or similar mottled pink acrylic. Upper anterior 1 × 6 Universal Verechrome mold S, M, or L-45F; shade Y or R3. Upper posterior 1 × 8. Identifying marks ground off. Clear palate. Unusual postdam as sketched.



Respectfully submitted,

J. P. PAULL
W. L. BALTEZAR
BUTTE DENTAL ARTS LABORATORIES
BUTTE, MONTANA

NEWS AND NOTES

MEETINGS

Dallas Mid-Winter Dental Clinic, Statler Hilton Hotel, Dallas, Texas, Jan. 22 to 25, 1961.

American Association of Endodontists, Conrad Hilton Hotel, Chicago, Ill., Feb. 2, 1961. For further information write to Dr. Edwin C. Van Valey, Secretary, 9 Rockefeller Plaza, New York 20, N. Y.

American Equilibration Society, Hubbard Room, Sheraton-Blackstone Hotel, Chicago, Ill., Feb. 2, 1961. For further information write to Dr. R. C. Van Dam, Secretary, 11431 South Halsted St., Chicago, Ill.

American Denture Society, Congress Hotel, Chicago, Ill., Feb. 3 and 4, 1961.

American Academy of Crown and Bridge Prostrodontics, Conrad Hilton Hotel, Chicago, Ill., Feb. 4 and 5, 1961.

American Academy of Restorative Dentistry, Conrad Hilton Hotel, Chicago, Ill., Feb. 4 and 5, 1961.

Chicago Academy of Dental Research, Seminar on Periodontics, Conrad Hilton Hotel, Feb. 4 and 5, 1961. For further information write to Dr. Sanford Schaffner, Director of Seminars, 10 North LaSalle St., Chicago 2, Ill.

Western Society of Periodontology, Tropicana Hotel, Las Vegas, Nev., March 19 to 21, 1961. For further information, write to Dr. Daniel Feder, 152 South Lasky Dr., Beverly Hills, Calif.

International Association for Dental Research, Hotel Statler, Boston, Mass., March 23 to 26, 1961. For further information write to Howard F. Campbell, 2000 P St., N.W., Washington 6, D. C.

American Association for Cleft Palate Rehabilitation, Montreal, Que., May 4 to 6, 1961.

Academy of Denture Prosthetics, Radisson Hotel, Minneapolis, Minn., May 7 to 12, 1961.

Southeastern Academy of Prosthodontics, Americana Hotel, Miami Beach, Fla., May 18 to 21, 1961.

Australian Dental Association, 16th Australian Dental Congress, Sydney, New South Wales, Aug. 14 to 18, 1961.

Pacific Coast Society of Prosthodontists, Empress Hotel, Victoria, B. C., Aug. 31 to Sept. 2, 1961.

ANNOUNCEMENTS

Reprints of the second edition of the *Glossary of Prosthodontic Terms* are now available. Prices: 1 to 20 copies, fifty cents each; 20 to 49 copies, forty cents each; 50 to 99 copies, thirty-five cents each; 100 or more copies, twenty-five cents each. Orders for less than 100 will be mailed prepaid; orders for 100 or more will be sent shipping charges collect. Cash, check, money order, or institution purchase order must accompany the order for reprints. Orders will not be filled otherwise. Address: Glossary Reprints, 3939 Old Brownsboro Road, Louisville 7, Ky.

Reprints of Reports Nos. 1 and 2, "Principles, Concepts, and Practices in Prosthodontics," may be obtained by writing Dr. W. Les Warburton, Secretary-Treasurer, Academy of Denture Prosthetics, 807 Medical Arts Bldg., Salt Lake City 11, Utah. The price is 25 cents for both, with a 20 per cent discount allowed on purchases of 20 or more. Cash, check, or purchase order *must* accompany the order.

BICENTENNIAL OF THE DEATH OF PIERRE FAUCHARD

Paris, July 1 and 2, 1961

This year, it will be exactly 200 years since the death of one that the profession throughout the world recognizes as "the inventor of modern dentistry."

The French dentists will commemorate this event with all the splendor that it calls for and are inviting their colleagues from all countries to join them. The complete program will be announced later, but some of the ceremonies have been arranged. A monument will be dedicated in the court of honor of the Chateau of Grand-Mesnil where Fauchard lived, at Orsay near Paris. A solemn ceremony will be held in the lecture room of the Sorbonne in the presence of members of the French government. *Le chirurgien dentiste (The Surgeon Dentist)* by Pierre Fauchard, which presently is practically unobtainable, will be republished. A postage stamp in honor of Fauchard will be issued.

The date of the ceremonies (July 1 and 2, 1961) was chosen in order to permit the greatest number of colleagues to participate. The date is between the Congress of the American Dental Society of Europe, in Paris (June 24 through 30), and the annual reunion of the Fédération Dentaire Internationale in Helsinki (July 9 through 16).

For further information write to M. Max Filderman, Secrétaire Général du Comité National du Bicentenaire de Fauchard, 67 Rue de Tocqueville, Paris XVIIe.

The American Association of Endodontists is sponsoring a symposium entitled, "Biology of the Dental Pulp," on Thursday, Feb. 2, 1961, at the Conrad Hilton Hotel, Chicago, Ill. Checks for the $25.00 fee should be made payable to the Association and forwarded to Dr. L. Parris, 1930 Chestnut St., Philadelphia, Pa.

Michael Reese Hospital and Medical Center presents "The Medical Laboratory in Clinical Dentistry," to be held on Feb. 9 and 10, 1961.

For further information write to Dental Department, Michael Reese Hospital, 29th St. and Ellis Ave., Chicago 16, Ill.

Loyola University, Chicago College of Dental Surgery, is offering a research and teacher training program in oral biology. This is under a teacher training grant from the National Institutes of Health. It is designed for candidates who desire a teacher's career in basic sciences or in clinical subjects. The stipends are up to $5,000 per year, and the program can lead to an advanced degree.

For further information and application write to Dr. Harry Sicher, Director, Loyola University, Chicago College of Dental Surgery, 1757 West Harrison St., Chicago 12, Ill.

Applications are now being accepted by the Graduate Division of the University of Pittsburgh, School of Dentistry, for graduate study in the fields of anesthesiology, oral surgery, orthodontics, periodontics, and prosthodontics leading to the Master of Science degree. Selection of students for the fall session of 1961 will be made in March, 1961.

A nondegree, full-time, 12 month course in general anesthesia is also available for qualified dental graduates.

Graduate study in the preclinical basic sciences of anatomy, biochemistry, microbiology, pathology, pharmacology, and physiology leading to the Master of Science or Doctor of Philos-

ophy degree is also offered through the Schools of the Health Professions. Successful applicants in this latter program are eligible for financial assistance in the form of traineeships.

For further information and application write to Director of Graduate Education, University of Pittsburgh, School of Dentistry, Pittsburgh 13, Pa.

Tufts University, School of Dental Medicine, announces two research fellowships in periodontology beginning September, 1961, and three full-time graduate courses in periodontology.

For further information and application write to Dr. Irving Glickman, Periodontology, School of Dental Medicine, Tufts University, 136 Harrison Ave., Boston 11, Mass.

Competitive examinations for appointment of dentists as officers in the Regular Corps of the United States Public Health Service Commissioned Corps will be held throughout the United States Jan. 31 through Feb. 3, 1961.

POSTGRADUATE COURSES

The University of Alabama, School of Dentistry, announces the following refresher courses:

Crown and Bridge Prosthodontics: Dr. John F. Johnston, Jan. 20 to 22, 1961.

Oral Roentgenology: Dr. Arthur H. Wuehrmann, Jan. 28 to 30, 1961.

Complete Denture Prosthesis: Dr. William L. McCracken, March 10 to 12, 1961.

For further information and application write to the Director, Refresher Course Program, University of Alabama, School Dentistry, 1919 Seventh Ave., S., Birmingham, Ala.

Boston University, School of Medicine, Division of Graduate Studies, Department of Stomatology, announces the following postgraduate courses:

Clinical Pathology of the Oral Mucous Membranes: Dr. Max Jacobs and Dr. Henry M. Goldman, Jan. 20 and 21, 1961.

Evaluation of Newer Dental Materials and Technics, and Factors Affecting Their Clinical Success: Dr. R. W. Phillips, Jan. 27 and 28, 1961.

Treatment Planning Clinic—Restoration of Missing Teeth: Department of Stomatology, Feb. 17 and 18, 1961.

One-Day Review of Endodontic Procedures: Dr. Herbert Schilder, Feb. 25, 1961.

Selection of Cases and Technics for Minor Tooth Movement: Dr. Leonard Hirschfeld, March 3 and 4, 1961.

Oral Pathology for Oral Surgeons: Dr. Jack Bloom, Dr. Kurt H. Thoma, and Dr. Henry M. Goldman, March 6 to 10, 1961.

Applied Anatomy of the Head and Neck: Dr. Arthur M. Lassek, March 10 and 11, 1961.

Seminar—Review of Occlusal Concepts in Restorative Dentistry: Dr. Morton Amsterdam, Dr. Ernest R. Granger, and Dr. Edward J. Hoffman, March 17 and 18, 1961.

The Abutment Tooth: Department of Stomatology, March 24 and 25, 1961.

The Use of Ultrasonics in Periodontal Therapy: Dr. Henry M. Goldman, April 1, 1961.

Apicoectomy-Surgical Endodontic Procedures: Dr. Herbert Schilder, April 10 to 14, 1961.

Periodontal Therapy: Dr. Henry M. Goldman, Dr. Bernard S. Chaikin, Dr. Gerald M. Kramer, Dr. William Pendergast, Dr. Jack Bloom, and associates, April 24 to 29, 1961.

Advanced Course in Periodontal Therapy: Dr. Henry M. Goldman, Dr. Bernard S. Chaikin, Dr. Gerald M. Kramer, Dr. William Pendergast, and associates, April 24 to 29, 1961.

Practice Management and Audio Analgesia: Dr. Frederick A. Trevor, April 28 and 29, 1961.

Head and Facial Pain of Dental and Non-dental Origin: Dr. Charles A. Kane and Dr. Kurt H. Thoma, May 13, 1961.

Full Mouth Reconstruction: Dr. Leo Talkov, Dr. David J. Baraban, Dr. Henry M. Goldman, Dr. Bernard S. Chaikin, Dr. Gerald M. Kramer, and Dr. J. David Kohn, May 15 to 19, 1961.

Pedodontics for the General Practitioner: Dr. Harold Berk, May 19 and 20, 1961.

Surgical Procedures in Periodontal Therapy: Dr. Lewis Fox and associates, May 22 to 26, 1961.

For further information write to Director of Postgraduate Studies, Department of Stomatology, Massachusetts Memorial Hospitals, 750 Harrison Ave., Boston 18, Mass.

The Medical College of Virginia announces the following postgraduate courses:

Clinical Occlusion: Dr. Arne G. Lauritzen, Feb. 11 to 15, 1961.

Oral Surgery: Dr. Elmer Bear and Dr. W. J. Longan, March 6 to 8, 1961.

Anatomy of the Head and Neck: Dr. Alton D. Brashear, March 13 to 17, 1961.

Complete Denture Prosthesis: Dr. M. M. DeVan, March 20 to 24, 1961.

Clinical Photography: Dr. P. J. Modjeski and Mr. Melvin C. Shaffer, April 10, 1961.

For further information and application write to Dr. H. T. Knighton, Director of Postgraduate Instruction, School of Dentistry, Medical College of Virginia, Richmond, Va.

New York University, College of Dentistry, announces the following postgraduate courses:

Immediate Dentures, Feb. 15 to 17, 1961.

Dental Obturators, March 15 to 17, 1961.

Partial Dentures, April 19 to 21, 1961.

For further information and application write to Director, Postgraduate Division, New York University, College of Dentistry, 421 First Ave., New York 10, N. Y.

Northwestern University Dental School announces the following postgraduate courses:

Practical Periodontal Treatment, Jan. 23 to 25, 1961.

Intermediate Oral Surgery, Jan. 30 to Feb. 3, 1961.

Current Concepts in Operative Dentistry, Feb. 1 to 3, 1961.

Pedodontics, Feb. 2 and 3, 1961.

Basic Oral Surgery, March 20 to 24, 1961.

Major Oral Surgery—A1, March 20 to 24, 1961.

Major Oral Surgery—A2, March 27 to 31, 1961.

Complete Denture Procedures, March 27 to 30, 1961.

A Practical Approach to the Use of Gold Foil, April 10 and 11, 1961.

Prosthetic and Orthodontic Rehabilitation for the Cleft Palate Patient, April 10 and 11, 1961.

Major Oral Surgery—B, April 10 to 14, 1961.

Oral Diagnosis, April 26 and 27, 1961.

Edmund Noyes Memorial Lecture, May 3, 1961.

The Use of Drugs in Dental Practice, May 8 to 10, 1961.

Recent Advances in Amalgam Techniques, May 15 and 16, 1961.

Conference for Teachers of Pedodontics, June 5 and 6, 1961.

For further information and application write to Northwestern University Dental School, 311 East Chicago Ave., Chicago 11, Ill.

The Ohio State University, College of Dentistry, announces the following postgraduate courses:

Crown and Bridgework: Dr. Thomas McBride, Jan. 23 to 27, 1961.

A Refresher Course in Dental Hygiene: Dr. Consuelo Wise and Dr. John Wilson, Jan. 30 and 31, 1961.

Pedodontics and Interceptive Orthodontics: Dr. Lyle Pettit and Dr. Benjamin Williams, Feb. 20 to 24, 1961.

Endodontics: Dr. J. Henry Kaiser, March 6 to 10, 1961.

Complete Denture Prosthodontics: Dr. Carl O. Boucher, April 3 to 7, 1961.

Hypnosis in Dentistry: Dr. Charles Pfersick, April 10 to 12, 1961.
Periodontics, Dr. John Wilson and Dr. William Walton, April 13 to 15, 1961.
Removable Partial Denture Prosthodontics: Dr. Victor Steffel, April 24 to 28, 1961.
General Anesthesia: Dr. Morgan Allison, May 15 to 19, 1961.
Dental Drugs in Action: Dr. W. Russell Kampfer, May 19 and 20, 1961.
Oral Surgery: Dr. Morgan Allison, May 22 to 26, 1961.
For further information and application write to The Ohio State University, College of Dentistry, 305 West Twelfth Ave., Columbus 10, Ohio.

The University of Pennsylvania, School of Dentistry, announces the following postgraduate courses:
Hypnosis Applied to Dentistry, Jan. 16 to 18, 1961.
Prosthetic Relations of the Temporomandibular Joint, Jan. 16 to 20, 1961.
Impacted Teeth, Jan. 25 to 27, 1961.
Cephalometry, Jan. 30 to Feb. 1, 1961.
Applied Anatomy, Feb. 22 to 24, 1961.
Partial Dentures, Feb. 27 and 28, March 1 to 3, 1961.
Diagnosis and Treatment Planning, March 6 to 10, 1961.
For further information and application write to Director of Postgraduate Courses, University of Pennsylvania, School of Dentistry, 4001 Spruce St., Philadelphia 4, Pa.

Tufts University School of Dental Medicine announces the following postgraduate courses:
A Course in Periapical Surgery, Jan. 26 and 27, 1961.
Crown and Bridge Design and Construction, Feb. 15 and 16, 1961.
Orthodontic Principles of Interest to the General Practitioner, each Wednesday, Feb. 8 through April 5, 1961.
Surgical and Prosthetic Management of Advanced Periodontal Disease, March 1 and 2, 1961.
Minor Oral Surgery, each Wednesday, March 1 through April 9, 1961.
Endodontics for the General Practitioner, March 20 to 23, 1961.
A Special Participation Course in Periodontology, April 24 to 28, 1961.
Clinical Adjustment of the Occlusion, May 3 to 5, 1961.
Special course in Surgical Management of Skeletal Deformities, May 8 to 10, 1961.
The Diagnosis and Treatment of Pain and Other Symptoms Arising From Temporomandibular Joint Disturbances, May 23 and 24, 1961.
Full Denture Prosthesis, June 5 to 9, 1961.
For further information and application write to Director of Graduate and Postgraduate Studies, Tufts University School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

HOSPITAL INTERNSHIP AND RESIDENCY PROGRAMS

The Veterans Administration Hospital, Iowa City, in affiliation with the State University of Iowa, College of Dentistry, announces that two rotating dental internships and one residency in prosthetics will be available for 1 year beginning July 1, 1961.
For further information and application write to the Chief, Dental Service, Veterans Administration Hospital, Iowa City, Iowa.

The Veterans Administration Hospital, Philadelphia, is now accepting applications for the 1 year rotating internships available July 1, 1961. The program is given in cooperation with the affiliated Dental and Medical Schools. A Certificate of Internship is awarded by the Hospital.
For further information and application write to Dr. S. L. Orlean, Chief, Dental Service, Veterans Administration Hospital, Philadelphia 4, Pa.

The Veterans Administration Medical Teaching Group Hospital of Memphis announces that two rotating dental internships and one residency in prosthodontics will be available for the year beginning July, 1961.

For further information write to M. Max Fildermann, General Secretary of the Comitté Administration Medical Teaching Group Hospital, Memphis, Tenn.

The Dental and Oral Surgery Service of The Mount Sinai Hospital in New York City announces that it is accepting applications for internships and residency for the calendar year beginning July, 1961.

For further information and application write to Dr. Max Fuchs, Assistant Director, The Mount Sinai Hospital, 11 East 100th St., New York 29, N. Y.

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Next Meeting: Americana Hotel, Miami Beach, Fla., May 18 to 21, 1961.

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